DISTANCE RUNNING

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Published privately in the United States of America

Printed by Sheridan Books, Inc., Ann Arbor, Michigan

ISBN: 0-9724144-0-1

Library of Congress Catalog Card Number: 2003093464

Book layout, cover design: Paul Lewis

Cover photo: The author running at Cannon Beach, Oregon, 1999. Photo by Shellie Lyden.

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DEDICATION

To my wife Shellie, our son Kieran,

and my parents for their love.

ACKNOWLEDGMENTS

I wish to thank the following persons and institutions for their assistance or contributions to this work: Per-Olaf Åstrand at the Karolinska Institute, Franz Berghold at the University of Salzburg, the late Bill Bowerman, Russell Burrows of New York, Forbes Carlile of Sydney, Australia, Karen Carpenter at Sports Illustrated, Peter Cavanagh at Penn State University, Nancy Cerutty of Portsea, Australia, Scott Cheshier and Corbis Photo Archives, David L. Costill of Muncie, Indiana, Edward F. Coyle at the University of Texas at Austin, George Dales of Kalamazoo, Michigan, Jack Daniels at Cortland State University, Erin Davis at Butler University, Bill Dellinger of Eugene, Oregon, Herb Elliott of Perth, Australia, Jim Ferstle of St. Paul, Minnesota, William H. Freeman at Campbell University, Edwin S. Fox and Jon Hendershott at Track & Field News, E.C. Frederick of Brentwood, New Hampshire, Rustem Igor Gamow at the University of Colorado, Roy Griak at the University of Minnesota, Joe Henderson of Eugene, Oregon, George Herringshaw and sporting-heroes.net of Leicester, England, Chick Hislop at Weber State University, Nobuya Hashizume of Plymouth, Minnesota, John Idstrom of Santa Cruz, California, Tom Ivers of Washougal, Washington, Peter Janssen of Deurne, Netherlands, Karl Keska of Wolverhampton, England, Damien Koch of Fort Collins, Colorado, B. Kummer at Sportverlag, Berlin, Chester Kyle of Weed, California, Arthur Lydiard of Auckland, New Zealand, Sarah Maddock at Penquin UK / Pelham Books, Milan Mader of Lakeville, Minnesota, John McKenzie of Fort Worth, Texas, Carolyn McMahon and AP / Wide World Photos, George Mitchell and USA TODAY Photo Archives, Melanie Moenig and Keystone Photos of Germany, Kenny Moore of Kailua, Hawaii, Klaus-Jürgen Müller and Heribert Simons at the University of Freiburg, Germany, Eric Newsholme at Oxford University and John Wiley & Sons Limited, Dr. Tim Noakes at the Sports Science Institute of Cape Town, South Africa and Retesha Thadison at Human Kinetics, Scott Pengelly of Eugene, Oregon, Steve Plasencia at the University of Minnesota, John Pottage of Mount Eliza, Victoria, Australia, Loan Osborne at Princeton University Press, Victah Sailer and Photorun of Smithstown, New York, Mike Salmon and the Amateur Foundation of Los Angeles, Ron Sass of White Bear Lake, Minnesota, Kristine Schueler and Allan Steinfeld at the New York Road Runners Club, Bob Sevene, of Boston, Massachusetts, Frank Shorter of Boulder, Colorado, Martyn Shorten of Portland, Oregon, Emil Siekkinen and Tomas Lindberg of Stockholm, Sweden, Graem Sims of Sydney, Australia, Bob Stewart of Shoreview, Minnesota, Susan Storch and the University of Oregon Archives—The Knight Library, Anthony Sullivan and Getty Images, Leo Tarantino at Duomo Photography, Edith Unold of Oetwil, Switzerland, Dr. Marc Wiessbluth at Northwestern University School of Medicine, and special thanks to George Dales and John Pottage for editing an early draft of the manuscript, and to Paul Lewis of Monterey, California for his contributions to the book layout and cover design.

CONTENTS

FOREWORD

This is the first really original work on distance training in several decades. Most recent books on this subject primarily focus on the physiology of training, and associated training schedules—essentially “man-as-machine.” These treatments give us no real philosophical underpinnings for sport, for training, and for their relation to life as a whole. They are one-dimensional theories dealing with multi-dimensional human beings. This book is a return to the “whole person” approach to training—once popular in the era of the great coaches like Bill Bowerman of the United States, Percy Cerutty of Australia, and Arthur Lydiard of New Zealand—where athletes are treated as more than just the sum of abstract physiological constructs, where heart and attitude and desire are as important, and perhaps more so, as measurable physical capacities. For every great champion, there are a hundred or thousand others with the same physiological traits, yet who fail to reach the same level.

This work is divided into four parts: (1) The Foundation and Principles of Training, (2) Strength, Flexibility and Injury Prevention, (3) Special Considerations for Distance Runners, and (4) Appendices, including the Training Schedules. The first part introduces a comprehensive model that reveals the structure, nature, and substance of the training process. In particular, Chapter 1 on Cycles of Acquisition and Training, provides elegant graphics by which the process of athletic development can be clearly visualized and understood. Chapters 2 through 6 address in consecutive order the Base, Hill, Sharpening, Peak, and Post-Season Recovery Periods, following their normal sequence during an athletic season. By the end of part one, you will have an excellent understanding of athletic training and be able to plan and illustrate entire seasons, and multiple years of athletic development.

The next two parts of the book, Strength, Flexibility and Injury Prevention, and Special Considerations for Distance Runners are devoted to often-overlooked essentials. Chapter 7 on Stretching, Flexibility and Movement, teaches a novel form of stretching especially suitable for distance runners, which draws upon particular teachings of *T’ai Chi* and *Yoga*. Certain aspects of the mind-body relationship are also discussed in relation to athletic performance. Chapter 8 expounds the importance of Strength Training for achieving success in distance running. This chapter also provides fitness guidelines for strength training and detailed weight training progressions. Chapter 9 reflects on Injuries and Athletic Shoes, examines numerous common running injuries and indicates possible

conformational, biomechanical, environmental and training errors that contribute to injury. It also examines the historical development of athletic footwear, and problems sometimes associated with specific footwear designs and constructions. The insights provided in this chapter may help you ask the right questions and make more informed choices when purchasing running shoes.

Part three, Special Considerations for Distance Runners, includes five chapters on specific factors affecting running performance, and concludes with two detailed chapters on the Steeplechase and Marathon. Chapter 10 reveals the dramatic effects of Shoe Weight and Mechanical Efficiency upon athletic performance. Chapter 11 on Iron Deficiency Anemia, provides vital information, guidelines, and certain precautions that can be discussed with a medical doctor. Chapter 12 considers the effects of Heat and Humidity upon athletic performance, and teaches how to prepare and successfully compete in these conditions. Chapter 13 on Altitude Training, explores various acclimatization scenarios associated with competition, and also the possible benefits of training at altitude for athletic performance at sea level. Chapter 14 examines the considerable influence of Aerodynamic Drag and Drafting upon athletic performance in the middle-distance and distance events. Chapter 15 addresses the highly specialized training required for The Steeplechase. Chapter 16 discusses training and competition in The Marathon, and raises worthwhile questions concerning participation in this popular event.

The Appendices offer detailed training schedules for runners competing at 800, 1,500, 3,000, 5,000 and 10,000 meters, as well as the marathon. This detailed illustration of how to apply the model and teachings provided in the first part is invaluable. The appendices also include sample schedules for bridging the gap between national championships and major international competitions, such as the World Championships or Olympic Games. These schedules will prove helpful to coaches and athletes facing these challenges for the first time, since relatively few athletes have numerous opportunities to compete in these international events.

The Glossary precisely defines the meaning of various terms used in this text. An extensive Bibliography has been included that should be useful to those who desire to pursue the subject further, and an Index has also been provided for easy reference.

This book is a welcome addition to the running canon. No serious coach or runner should be without it.

—William H. Freeman

Author, *Peak When It Counts.,*
Co-Author with Bill Bowerman,
High Performance Training for Track and Field,
Co-Author with Bill Dellinger,
The Competitive Runner's Training Book

PREFACE

This book originated with the expressed need of coaches and athletes who were searching for understanding and success in distance running. Both are faced with the challenge of acquiring the knowledge and wisdom of a lifetime—while still in their youth. Accordingly, this work is intended to provide you with the benefit of what other sucessful coaches and athletes have learned in their efforts to excel in distance running.

Within this text you will find a comprehensive model of athletic development that integrates discussion of relevant exercise physiology with detailed training programs for specific events. After finishing this book, you will be able to review your training diary and understand what happened, and also why it happened. You will better understand the implications of what you are doing at the present time, and be able to plan your training so as to peak and deliver your personal best performance at the right time and place. Moreover, the principles found in this text can be applied to many other physical activities and sports.

Early drafts of this work have circulated amongst coaches and athletes. As a result, it has been affectionately christened “The Cookbook.” Enjoy the recipes, but also strive to transcend them as you master the art. Upon attaining enlightenment, Zen students sometimes ceremoniously burn a copy of the sutras as an outward sign of mastery and liberation. Perhaps, you might instead make a gift of this book to someone else in need.

—Robert M. Lyden
Portland, Oregon 2003

PART I

FOUNDATION AND PRINCIPLES OF TRAINING

PHOTO 1.1—Bill Bowerman, legendary educator and coach at the University of Oregon, and co-founder of Nike, Inc. Photo by B.L. Freemesser, published by the Oregon Alumni Association, Old Oregon, February-March, 1960. Photo reproduced by permission.

CHAPTER 1

CYCLES OF ACQUISITION AND TRAINING PERIODIZATION

This chapter provides essential information concerning the structure and principles that govern athletic training. While challenging, it provides answers to the most fundamental questions associated with athletic training and development. The model is simple, yet comprehensive, and numerous figures are provided to help you grasp the key concepts. Once a few important relationships are understood, the mystery sometimes associated with training for distance running will be dispelled. As a result, coaches and athletes can plan their training and racing schedules with confidence and enjoy success.

Training Loads and Adaptation

The aim of athletic training is to bring about positive physical and mental adaptations to enable higher levels of performance. A *training load* is an appropriate stimulus, dosed so as to determine a progression effect in the training activity, (Pedemonte, 1982). Of course, we normally refer to training loads as workouts. The components of a training load or workout being:

- Quantity
  - Volume
  - Duration
- Quality
  - Intensity
  - Frequency
  - Density

Adaptation is the first law of survival, and a progression of suitable workouts can enhance athletic performance. However, work for the sake of work is not the answer. You must train intelligently in order to realize improvement. In this regard, planning workouts and performing them are two different things. Here lies the difference between an external training load and an internal training load. In simple terms, an external load is a workout written on a piece of paper. The internal load is the degree of effort the workout imposes on an athlete. For example, let's say two individuals are given the identical external training load of running a five-minute mile. However, one individual is a four-minute miler and the second a five-minute miler. Accordingly, the internal load placed on the first will be nothing compared to that placed on the second. The relationship between an external and an internal training load can be illustrated using the following interval

training session including: 4 (5 x 200 meters at 30 seconds) with a 100 meters jog recovery (jr) on the series (S), 200 meters jr on the series break (SB) or set, as shown in Figure 1.1.

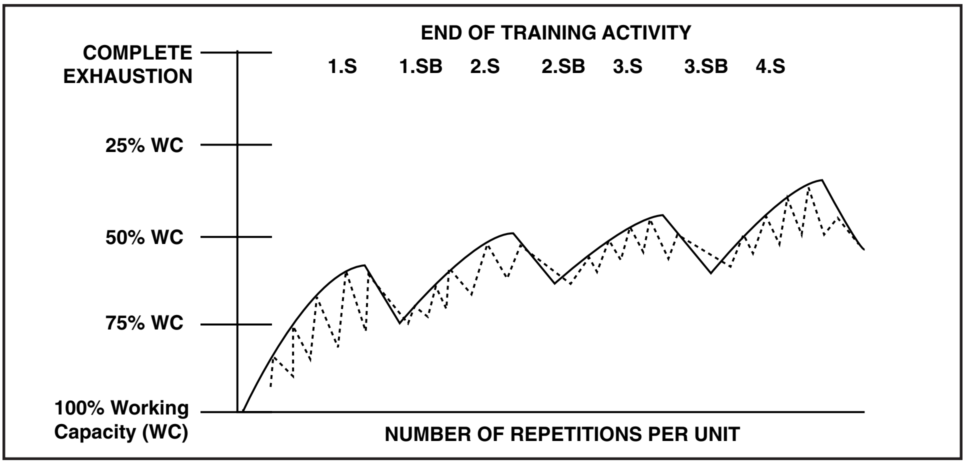


FIGURE 1.1—From Schmolinsky, 1978

As the workout progresses, maintaining the 200 meters series in the pace of 30 seconds requires greater effort. At the same time, maintaining the limited duration of the recovery period also becomes more difficult as the workout progresses. Given that an athlete enters the recovery period in a progressively higher state of fatigue as the workout continues, the recovery becomes progressively inadequate or too short, as compared to the earlier periods. As a result of the increasing internal load, the original recovery period is, in effect, being compressed during the workout. This can condition the athlete to physically and mentally put forth greater effort, and thus maintain the pace during an actual competition. Understanding the relationship between external and internal training loads can help an athlete shape the physical and mental conditioning taking place during training.

Coaches and athletes need to respect and focus upon the internal training load, that is, what is actually happening in a workout, as opposed to what they might have planned on a piece of paper. Do not attempt a planned workout if your body is telling you that it is not ready, or has had enough for the day. The body does not lie, but a piece of paper may do so. Trust, listen and attend to what your body tells you. Have a specific goal for each workout, and keep the workouts

simple. Beware of losing touch with reality when planning workouts, as abstract ideas can have an intellectual or emotional appeal when you put pencil to paper. So long as you accomplish the desired physical and mental tasks, simple is best.

The Effect of Training Effort on Improvement

Emil Zatopek, the Olympic Champion at 5,000 meters, 10,000 meters, and the marathon in the 1952 Olympic Games, once drew an analogy between the human body's response to a workout and the reaction of a spring. If you push the "spring" down a bit with a light training load, it will rebound in a relatively short time to a higher level than before. If you push the spring down with a heavier training load, it will take longer to recover and will rebound to an even higher level. However, be careful not to push too hard or too often, because you can damage the spring! (Spear, 1982).

This rebounding of the "spring" and an athlete's fitness to a higher level is commonly known as super-compensation. Accordingly, supercompensation is a cyclical phenomenon. When you undertake a training effort, your body becomes tired and your performance capability temporarily decreases. However, after a period of recovery, your body bounces back more fit than before. It is important to understand the practical effect that different training loads, or workout training efforts, have upon the rate of recovery and the amount of supercompensation. The essential unity of optimal loading and recovery constitutes the building block for all athletic development. The basic supercompensation model is shown in Figure 1.2.

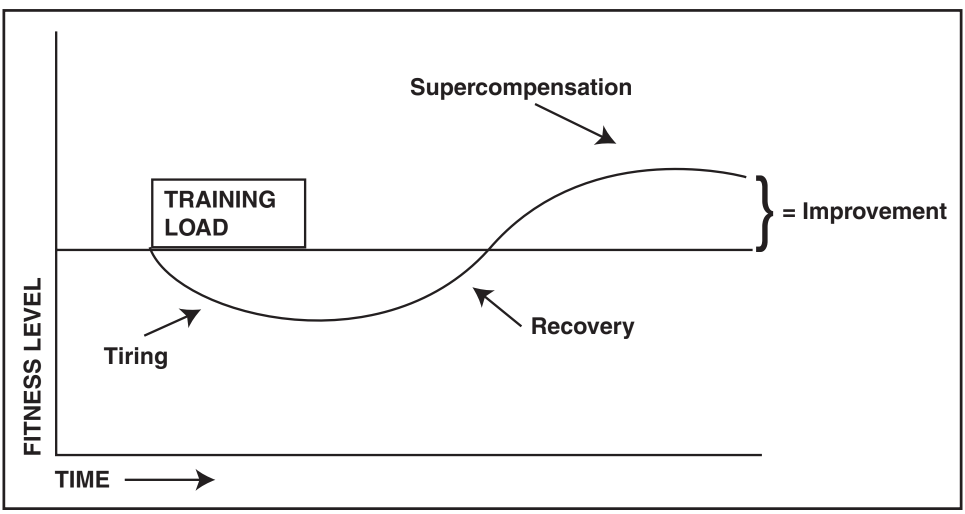


FIGURE 1.2—Supercompensation Model

This model represents only one possible training scenario. In reality, one of three different things can happen depending upon the magnitude of the training load in a given workout. The training load can either be:

1. *Too easy*—A training load that requires little effort provides for some supercompensation and improvement, but not a great deal as shown in Figure 1.3. This is commonly known as under-training. When under-training, athletes can conduct a workout without fear of hurting themselves, and the net result will still be positive.

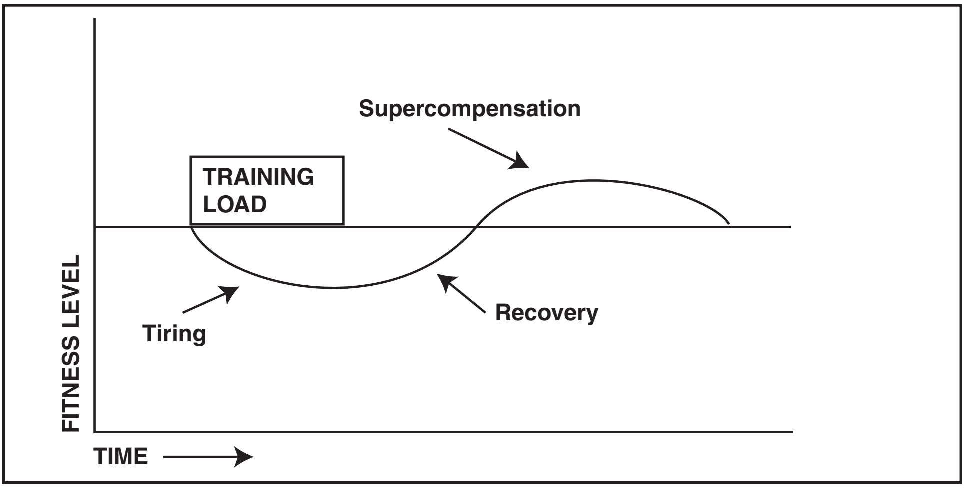


FIGURE 1.3—Under-training

2. *Too hard*—A training load that is too difficult can actually set an athlete backwards and result in a loss of fitness, as shown in Figure 1.4. This is commonly known as overtraining. Recognize that athletes can injure not only their muscles and tendons, but also their metabolism.

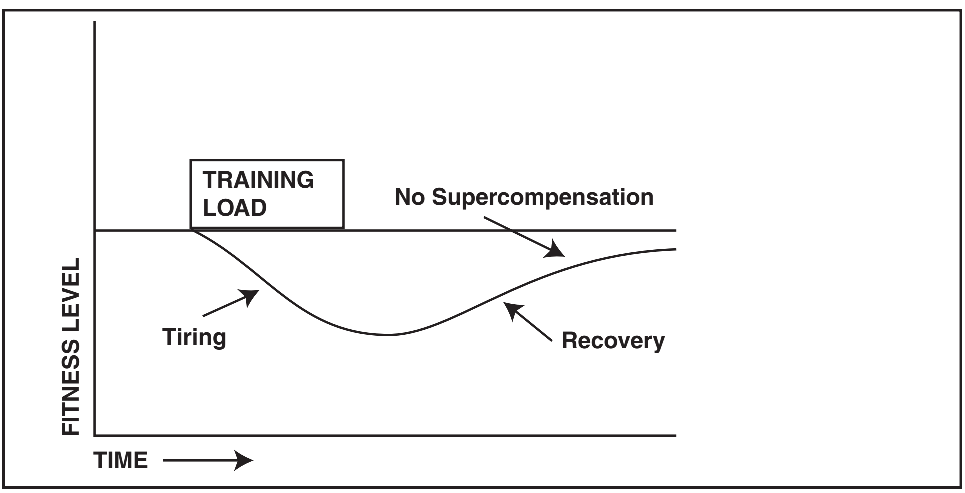


FIGURE 1.4—Over-training

3. *Just right*—A training load that solicits an optimal effort which provides substantial supercompensation and improvement, as shown in Figure 1.5.

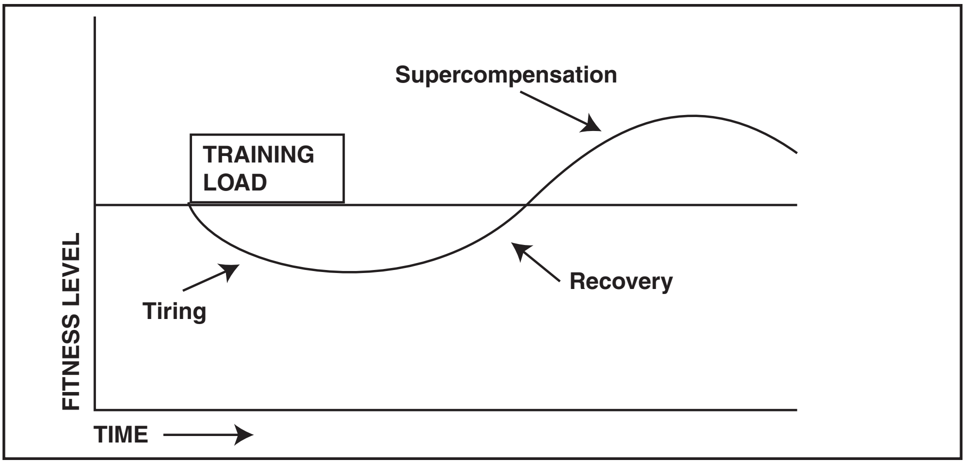


FIGURE 1.5—Optimal training

Figure 1.6 shows the alternate effects of under-training, optimal training, and overtraining on the rate of recovery and supercompensation. Figure 1.7 also shows the effects of various training efforts on the rate of recovery and supercompensation.

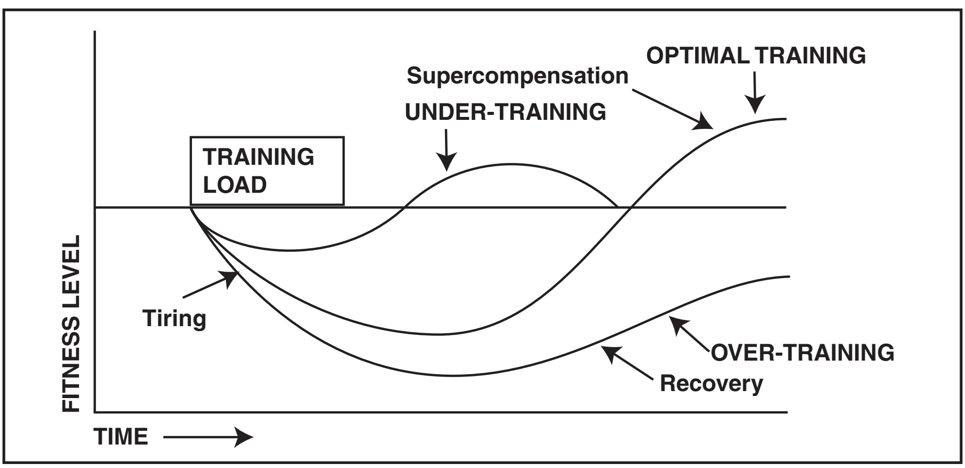


FIGURE 1.6—Three different resultants

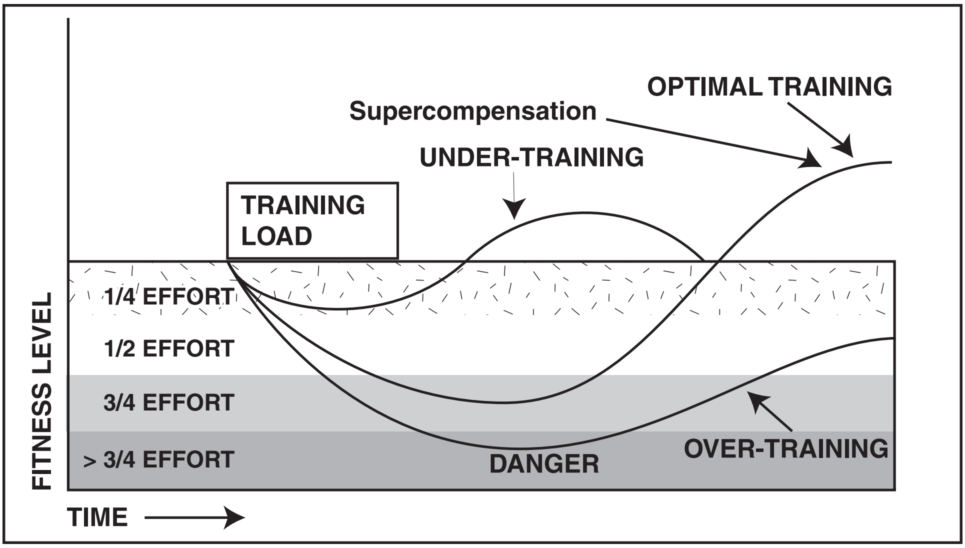


FIGURE 1.7—Three different resultants with effort levels

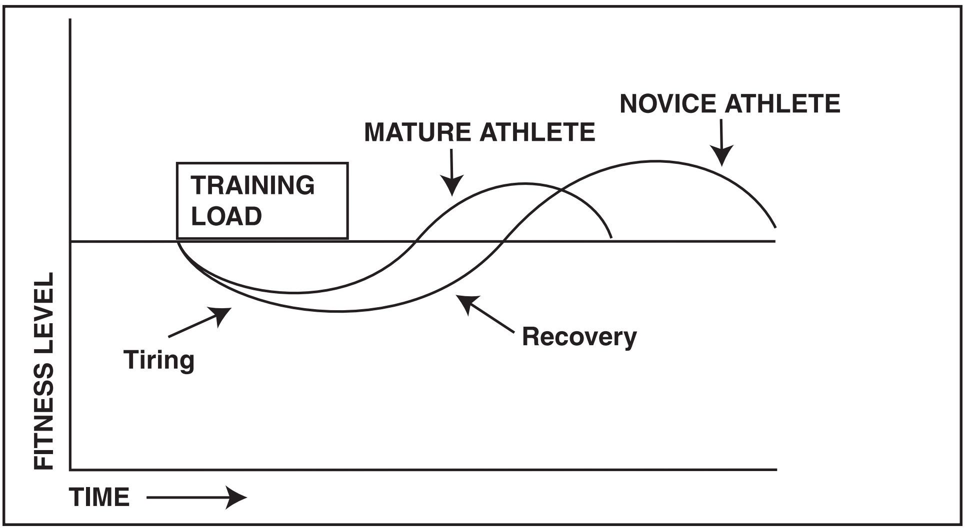


FIGURE 1.8—Different recovery rates

As shown in Figure 1.8, mature athletes recover faster from a given training load than their younger counterparts, but mature athletes do not as a rule enjoy as much resulting supercompensation, or convertibility from supercompensation to improved performances. Moreover, the suitability of any exercise for competitive training should be defined exclusively by how useful it is for developing performance in any given competitive event (Harre, 1982).

In light of the above, under-training is always better than overtraining. Under-training provides for some potential improvement, but overtraining actually

destroys athletic fitness. When in doubt, risk under-training rather than overtraining. As a rule, whenever coaches or athletes find themselves asking whether they should call it a day, *the mere posing of the question provides the answer.*

The Effect of Training Frequency on Improvement

Another important variable effects supercompensation and improvement: the training frequency as it relates to the summation of the supercompensatory effects. Here again, one of three things can happen, depending on whether succeeding training loads or workouts are properly timed:

1. *Too far apart*
2. *Too close*
3. *Just Right*

The proper time for an athlete to apply the next training load is while he or she is still at the peak of the supercompensation resulting from the preceding training load. In simple terms, an athlete first pushes down the spring, then allows it to rebound. The idea is to catch the spring while it is at the highest point of rebound and then to repeat the process. Consider what happens in the three scenarios indicated above.

Too far apart—If too much time slips by, the enhancement of ability is lost, and the athlete has to repeat the work all over again. From the standpoint of training frequency, the athlete is under-training. Figure 1.9 shows this by representing an athlete's fitness level on the left axis over time. There is no difference between the initial and final position on this axis, so no enduring adaptation or improvement in the athlete's performance potential has taken place.

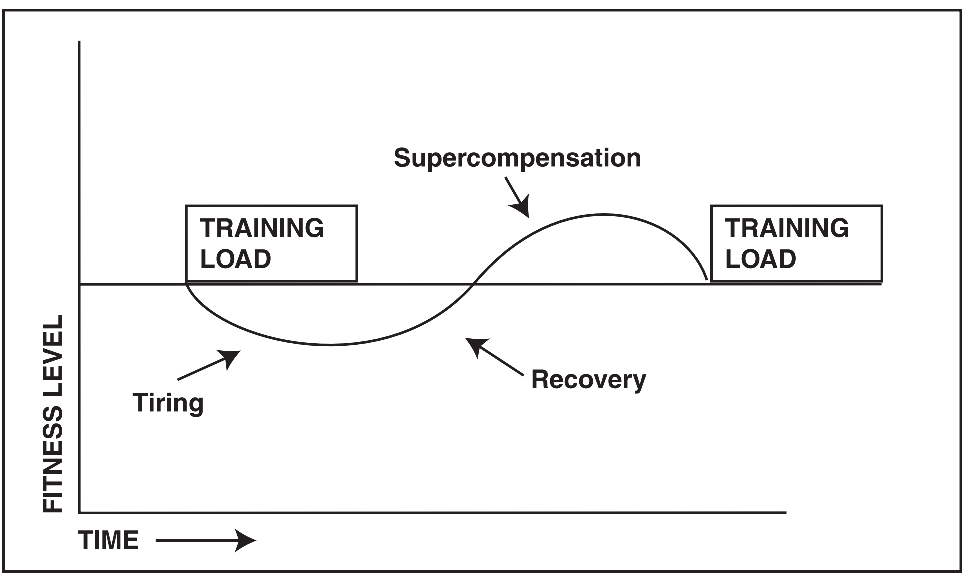


FIGURE 1.9—Training frequency too low.

Too Close—If succeeding workouts are placed too close together the result will be cumulative overloading and overtraining. In the abstract, the succeeding training load could be well within the athlete's capabilities, but in actual practice, coming too soon after the preceding training load, it will impose an overload while the athlete is insufficiently recovered. If a runner does not wait long enough for the resulting supercompensation to arrive, the process can be undermined and the athlete will then go backwards, as shown in Figure 1.10.

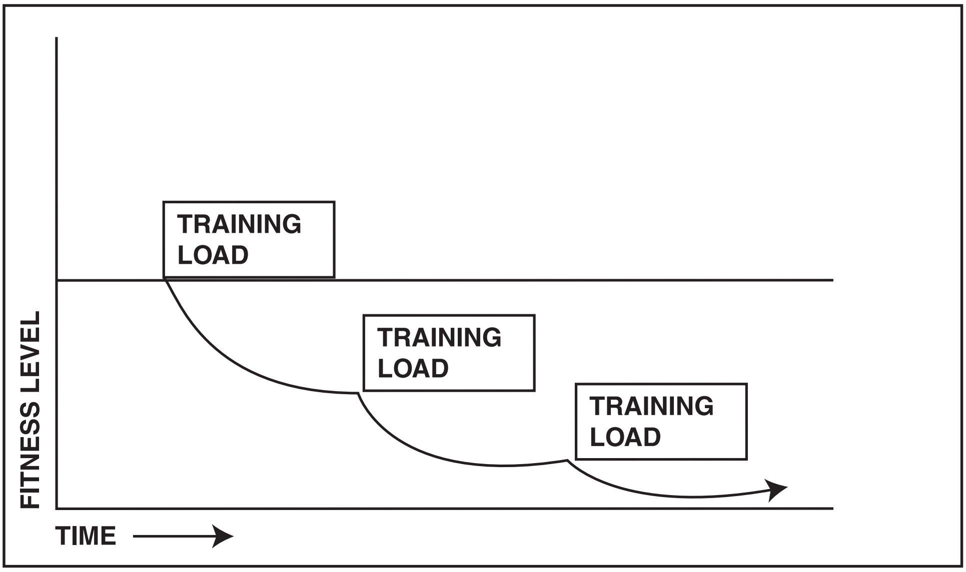


FIGURE 1.10—Training frequency too high.

In this case, from the standpoint of the frequency of training loads, an athlete is overtraining. The athlete will become more and more fatigued and the probability of illness or injury greatly increases. Over-training can result in the following symptoms commonly associated with overstress:

- Insomnia
- Illness
- Injury
- Anxiety
- Loss of appetite
- A higher resting pulse rate

Just Right—Given optimal training frequency, the timing or spacing of the training loads will be just right. As shown in Figure 1.11, the succeeding training load should be placed at the crest of the resulting rebound and wave of supercompensation. The difference between the initial and final position as indicated on the fitness level (left) axis indicates the amount of change or positive adaptation. This change corresponds to an improvement in the athlete's level of fitness and performance potential:

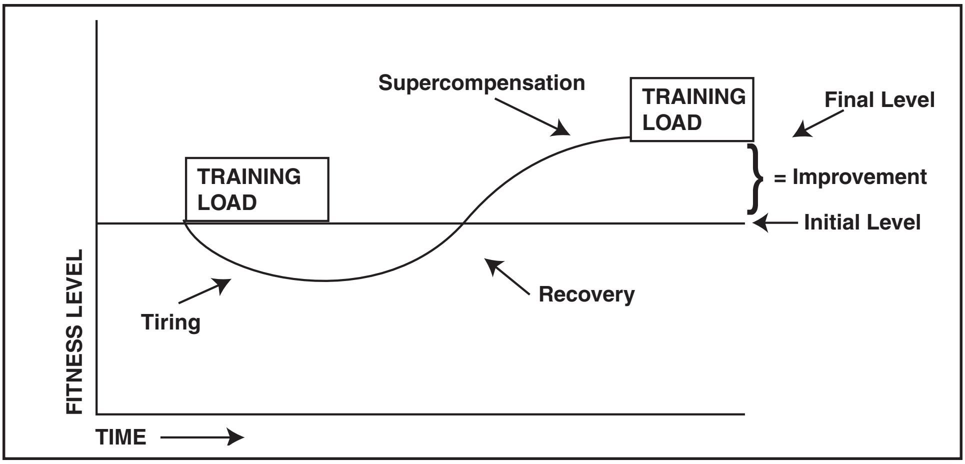


FIGURE 1.11—Optimal training frequency

Keep in mind that the training load tolerances and powers of recovery of individual athletes will vary. More mature athletes have greater training load tolerance and powers of recovery. Thus, relative to young athletes they require more frequent or heavier training loads in order to realize optimal improvement. In sum, the rebound of the spring results in improvement. The trick is to know what is a suitable training load and effort, and how long to wait in order to recover and catch the spring at the crest of the resulting rebound.

What constitutes 1/4-effort, 1/2-effort, and 3/4-effort workouts for mature and relatively fit athletes? And what is the length of the recovery period normally required afterwards? Table 1.1 correlates subjective effort with physiological response parameters (Adapted from Freeman, 1989).

EFFORT	INTENSITY	HEART RATE	% VO_2 MAX
FULL	MAXIMUM	190+	100+
3/4	SUB-MAXIMUM	180-190	90-100
	HIGH	160-180	70-90
1/2	MEDIUM	150-160	60-70
1/4	LIGHT LOW	130-150 110-130	50-60 30-50

TABLE 1.1—Example of an elite athlete. The maximum heart rate and response characteristics will vary greatly between different individuals.

In the training of mature and relatively fit distance runners, coaches often advocate the so-called hard-day/easy-day rule. However, this rule cannot be used in every circumstance. As shown in Table 1.1, training loads corresponding to 1/4-effort, 1/2-effort, 3/4-effort, and full-effort each require a different recovery period for an athlete to rebound, supercompensate, and then be ready for another quality training load. Given the various training loads commonly assumed by distance runners, the corresponding recovery periods are approximately:

- 24 hours, or 1 day following a 1/4-effort training load, or low intensity workout
- 36 to 48 hours, or 2 days following a 1/2-effort training load, or medium intensity workout
- 48 to 72 hours, or 3 days following a 3/4-effort training load, that is, a high or sub-maximal intensity workout—generally two such training efforts should be kept 3 to 4 days apart
- 72 to 96 hours, or 3 to 4 days minimum following a full effort, but as discussed below, most workouts should not exceed 3/4-effort

These parameters generally dictate the required training frequency between succeeding training loads or workouts for distance runners. Optimal training is a lot like playing music. If you play the right notes with proper rests, you have a melody, otherwise you have nothing but useless noise. Again, recognize that the more gifted, fit, or mature athlete possesses a faster rate of recovery from any given training load than a less gifted or fit individual. The former will rebound earlier and be ready for the next demanding workout while the latter is still tired and inadequately recovered. Therefore, the workouts must be individualized. Otherwise, the combination of quantity (volume and duration) and quality (intensity, frequency and density) could be ideal for one athlete, but counterproductive and perhaps even destructive to another. How do you accomplish this in practice? Let's say a coach is planning to have a boy's high school cross-country team conduct the following interval workout during the sharpening period: 4 (4 x 200 meters) at 32 seconds with a 100 meters jog recovery during the series, and 200 meters jog recovery at the set or series break. This workout could be fine for mature athletes who possess state championship potential, but the following changes could be made to individualize the routine for other team members:

- The quantity (volume and duration) could be reduced to perhaps just two sets for the freshmen, and three for the sophomores and less talented or less fit juniors and seniors
- The intensity could be reduced from 32 seconds to 34 or 36 seconds
- The density could be decreased by providing a 200 meters jog recovery during the series, and 400 meters at the set, or series break

In this way, athletes of all levels of ability can conduct the same type of workout on the same day, and the entire team can maintain the same training frequency. Normally, this is the best course of action when athletes having different levels of ability are following the same competitive schedule. An unfortunate situation can occur when workouts are constructed and directed towards only the most talented or mature athletes, and the rest are left to chase the leaders. As a result, the younger athletes overtrain, and soon experience residual or chronic fatigue problems. If and when they survive the process, the practical effect is to sharpen them faster than the mature athletes—that is, to give them more, when they actually require less! The younger athletes will then peak at a lower level of performance than they otherwise would, and relatively early in the season. Most of these athletes will then be on a downhill slope by the time of the championship competitions.

A training load having excessive magnitude can cause injury or exhaustion. As a result, athletes could be highly susceptible to illness and incapable of resuming demanding training for days or even weeks. Accordingly, the dose of training that will produce a supercompensatory effect has a practical limit: Optimal training loads do not normally exceed 3/4-effort. Optimal training does not correspond to maximal effort. However, a 3/4-effort for an elite runner generally corresponds to a heart rate between 160 and 190 beats per minute (bpm). This level of effort is no “walk in the park” by layman’s standards.

All things being equal, the greater the training load, the longer the requisite period of recovery—and within certain limitations, the greater will be the supercompensatory effect. But remember, nothing in the various figures and tables found herein determine an athlete’s response. It takes much to build, but little to destroy. *A single workout can end an athletic season or career.* Moreover, the price of freedom of the will is a degree of indeterminance in human affairs, and so we face the machinations of chance. The coach and athlete should attempt to reduce, if not completely eliminate the influence of chance or so-called luck on the course of events. In short, those who aim for success strive for certainty. A large part of what passes for luck stems from a positive attitude and a habit of doing all those so-called extra “little” things. They are not extra, nor are they little, because by the end of a season they add up a mountain high!

MICRO-CYCLES: THE WEEKLY VIEW OF ATHLETIC TRAINING

In the course of the preceding discussion and illustration of supercompensatory effects, load-wave phenomena have been introduced. The graphs depict so-called short load-waves corresponding to what are commonly called micro-cycles—the interfacing of day-to-day training, or weekly view of athletic development. We can now address the indissoluble unity of the cycles (loading, recovery, supercompensation, higher loading) and the interfacing of succeeding supercompensatory effects that are characteristic of micro-cycles.

Again, improvement results from a correct alternation of loading and recovery. As shown in Figure 1.12, suitable workouts of varying effort are conducted successively, following appropriate recovery periods. The difference between the initial and final position on the vertical axis indicates the amount of improvement, and the slope of the line drawn between any two given points indicates the rate of change with respect to improvement.

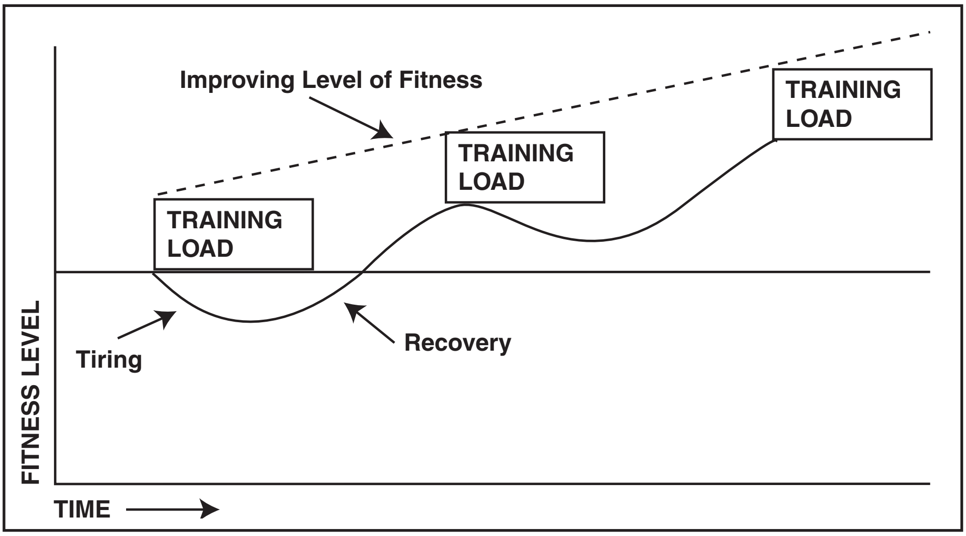


FIGURE 1.12—Micro-cycle loading waves

It is now possible to depict the complex and delicate relationship between optimal loading and recovery required for significant athletic development. In contrast, Figure 1.13 shows a complex series of hypothetical effects that can result from poorly administering the various indicated training loads and recovery periods.

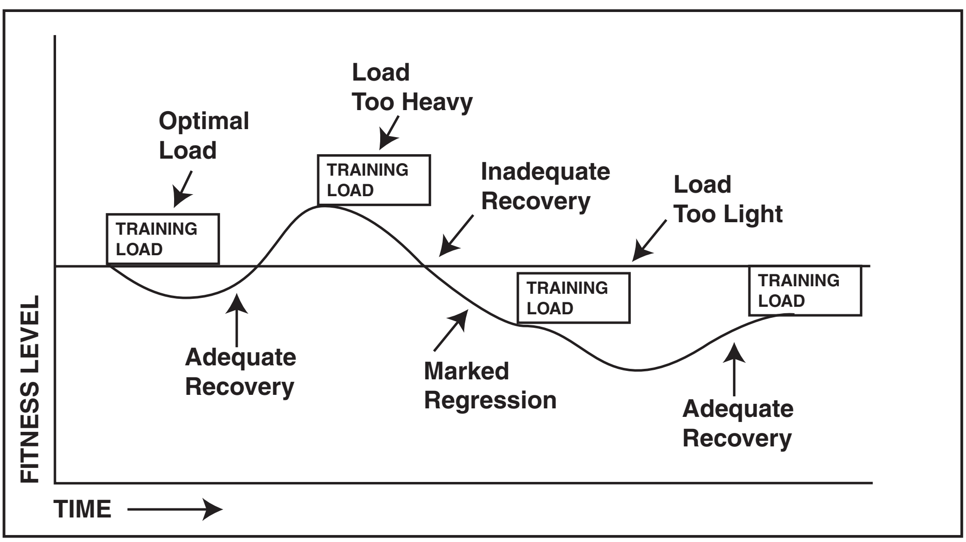


FIGURE 1.13—Various training loads and frequency

In mathematics and physics, a vector represents direction and magnitude. Here, an individual vector arrow can be used to represent the result of each individual supercompensatory cycle by showing the magnitude of gain or loss, and also the direction over any given time period. Moreover, the slope of each vector indicates the rate of change for any given interval of time. Further, adding a given string of individual vectors tip-to-tail determines the final product of an extended series, thus deriving the larger resultant vector. The individual and resultant vectors can sometimes be used to illustrate the momentum developed by a series of training efforts. Again, the larger resultant vector sums the entire group of individual events, and its slope represents the rate of change over the entire series, as shown in Figures 1.14 and 1.15.

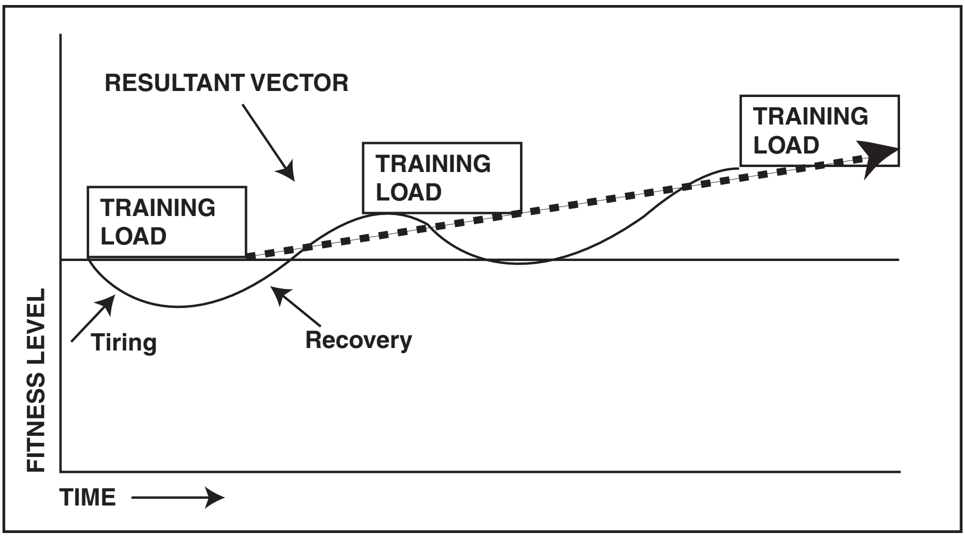


FIGURE 1.14—Vector = direction and magnitude of change

An ideal unity of loading and recovery fosters optimal athletic development, because the athlete successively assumes optimal training loads after appropriate recovery periods. The difference between the initial and final position on the left axis indicates the amount of change and positive adaptation. If the training loads suit an individual's athletic development, this change directly corresponds to improvement in the runner's performance potential.

As shown in Figure 1.15, the resultant vector indicates the end result of a series of non-optimal training events. The difference between the initial and final position represents the change in performance potential. The slope [slope = change in y (vertical) over change in x (horizontal)] of this resultant vector indicates the rate of change in performance potential.

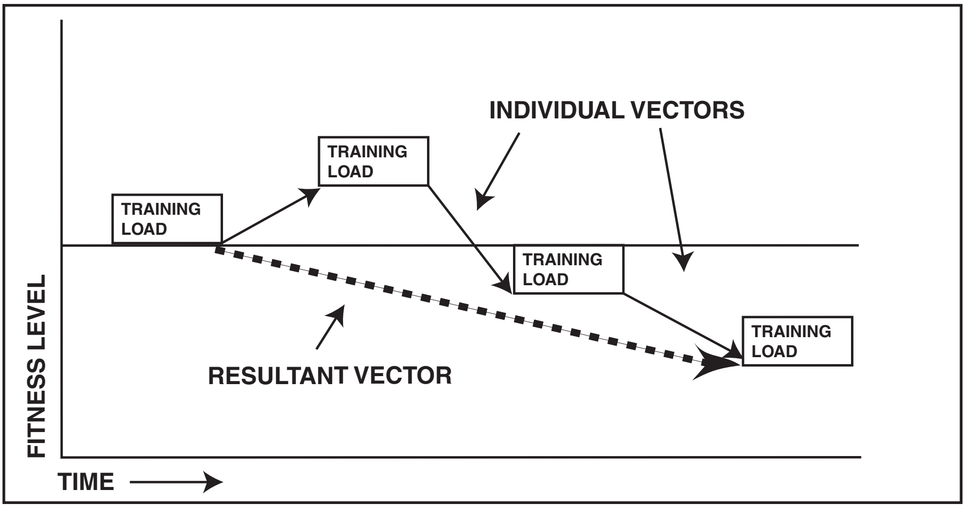


FIGURE 1.15—Individual and resultant vectors

Coaches or athletes would do well to take their training schedule or diary and to diagram the various training loads and recovery periods. Seeing is believing. Due to the importance of our visual sense, this exercise can provide clarity and understanding. Figure 1.16 shows an example of a micro-cycle for possible use during an athletic season:

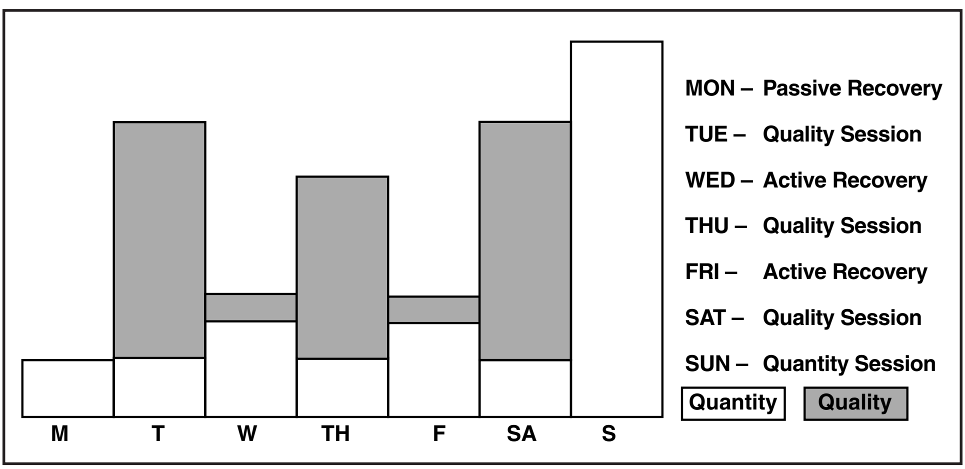


FIGURE 1.16—Micro-cycle example

When using this weekly model or training schedule during the base period, a 3/4-effort anaerobic threshold session would be conducted on Tuesday, a 1/2-effort fartlek session on Thursday, and a 3/4-effort evenly paced steady state on Saturday. During subsequent hill and sharpening periods, days of heavier training loads would again be placed on Tuesday and Saturday. This consistency results in better acquisition and a faster rate of athletic development. The content of the passive and active recovery sessions undertaken on Monday, Wednesday, and Friday are essentially unchanging. Whenever possible, throughout the base, hill, and sharpening periods, retain a 1/2-effort fartlek session on Thursday, and an easy long run on Sunday.

Obviously, associating specific days of the week with particular training tasks is quite arbitrary, serving only as an illustration. It is the pattern and balance of the training that is important. The special needs and requirements associated with delivering optimal performance renders the nature of the activities undertaken during the peak period a special case. Once within the peak period, an athlete is largely sustained by the momentum gathered during the preceding athletic season. However, from the standpoint of enabling optimal performance, this momentum will run its course in just a few weeks.

It is now possible to consider medium load-waves, or meso-cycles—the interfacing of micro-cycles, or weeks of training, to create what could be called the monthly view of athletic development. Following this, long load-waves, or macro-cycles, associated with entire competitive seasons, and finally mega-cycles, which correspond to multiple years of training, can be addressed. However, the micro-cycle is the most critical in its immediate effect upon an athlete. It is the basic building block or *sine qua non* upon which the larger cycles and periodization of training depend.

MESO-CYCLES: THE MONTHLY VIEW OF ATHLETIC TRAINING

The coach and athlete should now be able to visualize and diagram the day-to-day training program and plan several weeks of training. However, the preceding information is insufficient for the purpose of successfully planning an entire athletic season. Consider the following:

Question: Even if you manage to conduct workouts with optimal effort and training frequency, can you continue to train indefinitely and realize improvement?

Answer: No. It is not possible. Even if you provide training loads with appropriate effort, as determined by the quantity (volume, duration) and quality (intensity, density and frequency), it is simply not possible to train strenuously for an indefinite period of time and continue to realize improvement. The primary problem involves the onset of residual fatigue.

The Role of Variation in Preventing Fatigue

The brief recovery periods taken between individual workouts deal effectively with the phenomenon of acute fatigue. Specifically, you work hard and get tired, but over a period of a few hours or days, you recover. However, if you continuously train over many days or weeks, your body may be unable to keep up with the much larger demands placed upon it. As a result, your body can become depleted of essential mineral salts and nutrients. For example, when athletes deplete their calcium, potassium, magnesium, or phosphorus, they can experience lingering muscular fatigue and become susceptible to stress fractures. When runners deplete their iron, they risk a bout with anemia. The solution may be as simple as eating well, avoiding things associated with depletion—such as hard training efforts, sun tanning, saunas, and diuretics—and resting your way back into shape.

Many other biochemical processes can also be compromised and result in the onset of residual fatigue. If, over a long time an athlete ignores the warning signs of residual fatigue and does not attended to them, a more serious condition can result, known as chronic fatigue, or the so-called “burned-out” syndrome. To use the analogy of a factory, it is not then a matter of being out of the materials required for production, rather, there has actually been some damage done to the factory itself. In particular, the body’s ability to make and use essential hormones associated with the endocrine system, and to maintain the delicate balance between anabolic and catabolic processes can be adversely affected.

Any number of processes in the body can go awry when residual fatigue progresses to the point of causing a state of chronic fatigue. Once this happens, the coach or athlete has opened a Pandora’s Box of troubles. Chronic fatigue syndrome can result in serious physical and mental breakdown, and can be potentially life threatening. An essential part of the solution includes the cessation of hard work and competition, and going out to pasture for a while. Professional medical help should be sought to properly diagnose and treat the condition. This could include both an endocrinologist and a clinical psychologist. However, beware of seeking medical assistance for a quick fix, such as medication, only to continue upon the path of overtraining and possible self-destruction. This may bring a period of apparent “recovery,” but afterwards, an athlete can become even more seriously affected, and possibly addicted to the medication. When the body habitually gets something for nothing, the “factory” normally responsible for manufacturing that something within the body often curtails its production and shuts down, perhaps never to start up or function as well again. Unfortunately, many take the pharmaceutical approach to solving chronic fatigue problems. In the short term, this method is easier and less costly than teaching an athlete how to train properly or change their mental outlook and behavior. And when the problem lies with faulty athletic training, few doctors or psychologists have the knowledge to assist in this area. When your body suffers a breakdown, it is telling you that you have violated a natural law. Ultimately, athletes need to educate themselves and take responsibility for their own physical and mental health.

The Role of Variation in Preventing Habituation

Variation not only serves to dodge the onset of residual or chronic fatigue, but also prevents habituation. Over time, the human body grows accustomed to any given type of training load or workout. As the athlete's body habituates to the would-be training stimulus, physical and mental stagnation is the most likely result. In this case, there is a direct relationship between an athlete's physical state and mental state. In time, as the athlete habituates to a workout, the magnitude of positive adaptation will decline, if not cease altogether. What once provided a suitable physical and mental stimulus now comes to resemble a state of equilibrium. On the mental side, this produces a decline in the athlete's interest and motivation. The athlete becomes bored with the dull routine and loses enthusiasm.

Workouts must vary from day to day and week to week. Moreover, the potential enhancement of fitness created by the individual training sessions needs to be stabilized and consolidated. Variation and recovery are necessary, not only with respect to the day-to-day composition of training, but also with respect to larger blocks of work consisting of several days or weeks. Accordingly, if athletes want to continue improving, they must periodically take a worthwhile break. To allow the body to recover, they should take a respite from hard training lasting between seven and 14 days. So, after a period of continuous training lasting days or weeks, the training loads should be eased in order to avoid the onset of residual fatigue and habituation. This also permits the proper stabilization and consolidation of performance potential created by previous hard work. Thereafter, athletes will be able to resume training until they once again require a subsequent worthwhile break. In this regard, training is a lot like climbing a ladder, or laying bricks. If athletes try to take too many rungs too quickly, they will miss one and take a fall. Alternately, if they lay too many bricks before the mortar has had a chance to set properly, then the entire structure could tumble down, and the athletes would have to start over again.

Often, runners fear to back off and take a worthwhile break, because they think someone else is out there training hard and getting ahead. They need to be reminded that a worthwhile break forms an integral part of the larger process of acquisition and improvement, and that the activities of others have nothing to do with their own athletic development and fitness. An old Zen story tells about a student being impatient and disappointed upon hearing that it would take five to ten years to attain mastery of a certain martial art. He asked his master what would happen if he tried twice as hard. The master replied that it would then take him twice as long to reach his destination.

The importance of introducing variation with respect to consecutive weeks of training, thereby creating blocks of training, will now be addressed. Here it is necessary to address medium load-waves or meso-cycles, which correspond to the monthly view of athletic training and development.

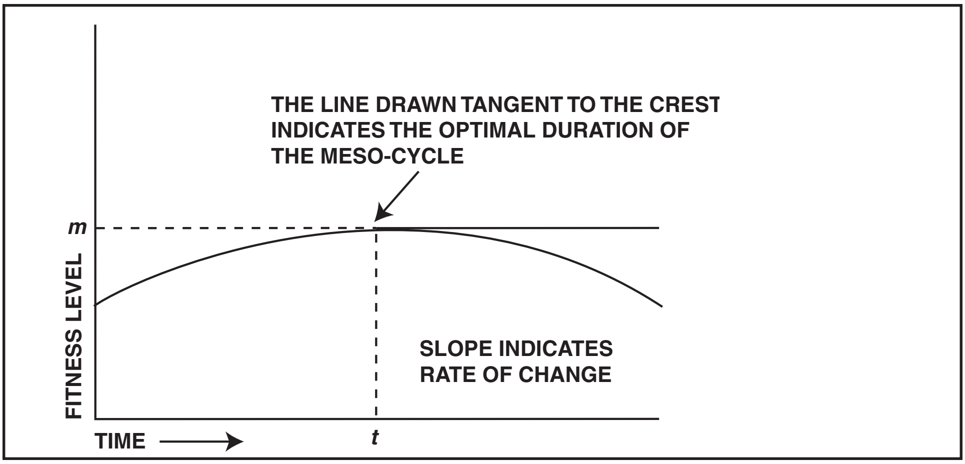


FIGURE 1.17—Training regression

Meso-Cycle Structure and Duration

Again, after days or weeks of demanding training, the rate of acquisition and performance potential of the athletes will eventually crest. With the onset of residual fatigue, if runners continue with demanding training they can actually suffer a regression in fitness and go backwards. As shown in Figure 1.17, maximum fitness (*m*), being achieved at time (*t*), with a subsequent decline in fitness, indicates that the duration of the meso-cycle ought not to exceed *t* days.

Question: How long can athletes train before they need an easy worthwhile break?

Answer: It all depends upon the degree to which they tax their metabolism. Weight lifters can sometimes train for five to six weeks without requiring a worthwhile break. At the beginning of the base period, distance runners can normally undertake three to four weeks of training before requiring a worthwhile break, but as the quality of the training loads increase during the course of the athletic season, they will need to cut back to 21-day, 14-day, and ultimately, 7-to-10-day meso-cycles.

However, a middle-aged athlete who resumes training after a long lay-off could require a worthwhile break after the first week of training. If you are unfit and attempting to train for the first time, you might even require a break after just a few days. It could take a while for you to become fit enough to put two weeks of continuous training together. Even mature athletes might require a worthwhile break after a week of training if they increase their training loads too aggressively. For example, athletes who suddenly increase their mileage from 80 to over 100 miles per week may require a worthwhile break the following week. It could take several weeks or even months for these athletes to be capable of sustaining 100 mile per week.

Question: How do you know when to take a worthwhile break?

Answer: After a 3/4-effort workout, it is not abnormal to be fatigued and recovering for two or even three days, but this fatigue should not linger for much longer. Any time athletes expect to be recovered but find themselves still fatigued, and two similar days follow, they could be suffering from the effects of residual fatigue. At that point, athletes could actually be going backwards in their training. One or more of the following symptoms can warn of this impending condition: insomnia, illness, injury, anxiety, loss of appetite, and a higher resting pulse rate. As a normal training practice, athletes do not want to run themselves into a state of residual fatigue. Athletes should plan and conduct their training so that they take a worthwhile break before they encounter signs of overtraining or other difficulties. An experienced coach or athlete will be able to predict with great accuracy how long the athlete can train before a worthwhile break is needed. If you do not intelligently plan a worthwhile break, then the body will force you to do so at a time that could prove especially disadvantageous. If you do not control the process, then it will control you—and more often than not, to the detriment of your athletic goals.

In brief, the greater the training loads and stress on the metabolism, the more frequently athletes require a worthwhile break. Thus, as an athletic season progresses (and with it, the quality of the work being conducted), the meso-cycles shorten in duration and increase in frequency. Figure 1.18 shows the optimal time for introducing a worthwhile break given the training loads being conducted during the various training periods.

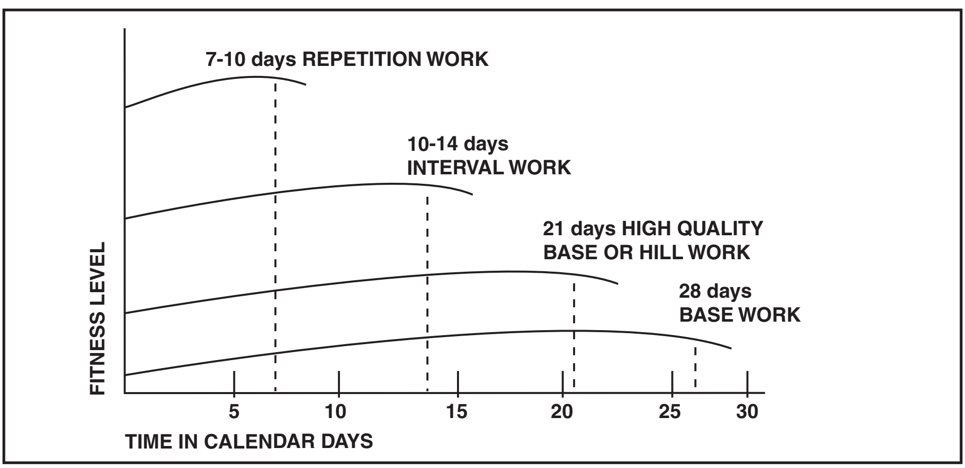


FIGURE 1.18

Generally, 21 to 28 days of base work, or 21 days of hill work, or seven to 10 days of sharpening work can be undertaken before athletes need a worthwhile break. Remember, a maximum of two 3/4-effort workouts and one 1/2-effort workout can be conducted during a typical week. So working backwards, runners can conduct a maximum of two or three 3/4-effort interval or repetition workouts over seven to 10 days, perhaps six 3/4-effort hill workouts over 21 days, and between six and eight 3/4-effort anaerobic threshold and steady state workouts over a period of 21 to 28 days. If runners attempt to exceed any one of these prudent limits—they will often run straight into trouble.

When runners attempt to squeeze in "just one more" demanding workout, and encounter substantial residual fatigue, then the price to pay can easily be a 10-to-14-day recovery period. So trying to get one workout "ahead" can easily put an athlete one or two weeks behind. And if an athlete thereby becomes injured or ill, the price to pay can easily be the desired outcome of the current athletic season. As we have seen with the micro-cycle or weekly view of athletic training, it is better to under-train than over-train. With the meso-cycle or monthly view of athletic training, this is doubly important. If and when athletes make a mistake with a larger training cycle, they pay a greater price.

Meso-Cycle Structure and the Consolidation and Stabilization of Fitness

Habituation to training can be avoided by introducing well-timed worthwhile breaks. Also, by shifting from general to more specific training tasks, variation can be introduced within the larger meso-cycle. In truth, it is necessary to shift the emphasis of the training program to specific tasks such as the conduct of time trials or competitions, since these cannot be performed to good effect when suppressed by previous hard work. Every coach and athlete needs to appreciate this simple, but profound truth: hard training suppresses performance. It is impossible for athletes to conduct a time trial or compete to good effect when insufficiently recovered from demanding training. If and when they make such an attempt, they cannot deliver optimal performances, and their true level of fitness could be difficult to discern. More importantly, when demanding training suppresses the quality of the time trials or competitions, stabilization and consolidation of the potential improvement created by the training efforts will be thwarted.

The task of stabilizing and consolidating the potential created by previous hard work is accomplished by taking a worthwhile break lasting between seven and 14 days, and then conducting a time trial or competition at the end of the worthwhile break. At that point in time, the actual performance level of the athletes will then rebound and reflect their true performance potential. Thus, athletes should not race in practice, nor practice in races. They should not "train through"

races and make a muddle of the acquisition process. That would be counterproductive to obtaining the physical and mental fitness required for superior athletic performance.

Again, a direct relationship exists between the worthwhile break and realizing improvement. Athletes train for a length of time in order to raise their performance potential, but it is only potential because they have not actually performed at this new level. When fatigued from demanding workouts, they will not be able to demonstrate their performance potential. Accordingly, the worthwhile break must be introduced. The end of the worthwhile break then concludes with a time trial or competition, which serves to stabilize and consolidate the potential enhancement of performance created by previous acquisitive training efforts. Performance potential can then be realized as actual performance. The time trial or competition also provides a concrete reference point with respect to the athletes' level of fitness. The information it provides can then be used to reevaluate the training plan for the next training meso-cycle.

Meso-Cycle Structure and Load Leaping

By adapting the height, size, and shape of a block of training, the magnitude of training loads assumed over time can be represented as a percentage of maximum working capacity. As shown in Figure 1.19, athletes can progress from lower to higher training loads consistent with the model of Matveyew. Alternatively, they can begin with higher training loads and then back off consistent with the model of Vorobyew. More complex models will be provided later in this chapter.

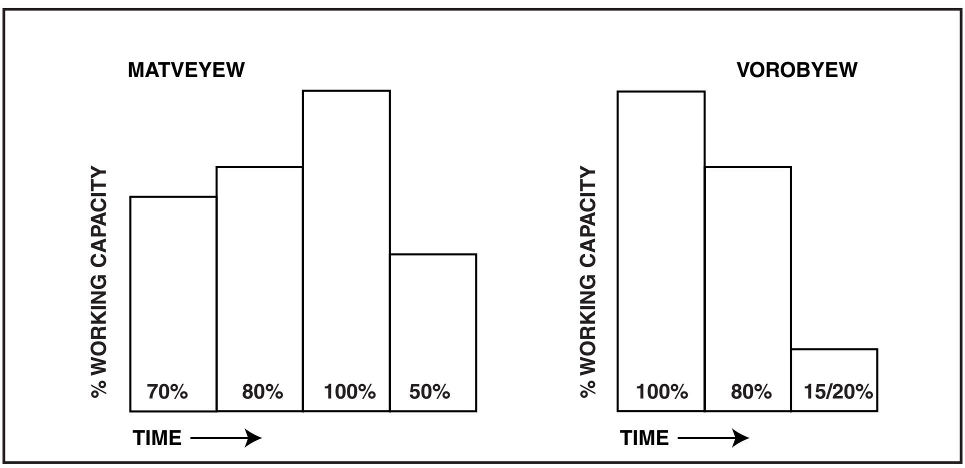


FIGURE 1.19—From Schmolinsky, 1978

Figure 1.20 illustrates the effect of a series of weekly training loads on potential and actual performance levels. Here, the bar columns, indicating the magnitude of the training loads and the percentage of working capacity assumed by the athletes, properly support the solid blue line representing their performance potential. The broken red line, indicating the actual performance level, reflects the degree that hard work suppresses their performance potential. The symbol X indicates a time-trial or competition at the end of the worthwhile break to consolidate acquisitive training efforts and check on athletic development. At this point, the performance potential and actual performance of the athletes are both approximately at the same level, and these lines should intersect. Alternating a series of blocks of hard training with required worthwhile breaks within a meso-cycle is commonly called load-leaping.

Provided here are abstract 14 and 21-day acquisitive meso-cycles corresponding to work conducted during the base, hill, or sharpening period.

14-DAY MESO-CYCLE	21-DAY MESO-CYCLE
1 Passive Recovery	**1** Passive Recovery
2 3/4-Effort, Quality Session	**2** 3/4-Effort, Quality Session
3 Active Recovery	**3** Active Recovery
4 1/2-Effort, Quality Session	**4** 1/2-Effort, Quality Session
5 Active Recovery	**5** Active Recovery
6 3/4-Effort, Quality Session	**6** 3/4-Effort, Quality Session
7 Active Recovery	**7** Easy-effort, Long Run
8 Easy-effort, Long Run	**8** Passive Recovery
9 Passive Recovery	**9** 3/4-Effort, Quality Session
10 3/4-Effort, Time Trial	**10** Active Recovery
11 Active Recovery	**11** 1/2-effort, Quantity Session
12 Easy Recovery	**12** Active Recovery
13 Day Before Race Routine	**13** 3/4-Effort, Quality Session
14 Race	**14** Active Recovery
	15 Easy-effort, Long Run
	16 Passive Recovery
	17 3/4-Effort, Time Trial
	18 Active Recovery
	19 Easy Recovery
	20 Day Before Race Routine
	21 Race

Meso-Cycle Structure and Duration of the Training Periods

Based on the preceding discussion, it will now be possible to address the meso-cycle structure and also the duration of the base, hill, sharpening, peak, and post-season recovery periods in an athletic season. Ultimately, the number of competitive athletic seasons assumed during the calendar year, and the length of the hill, sharpening, peak, and post-season recovery periods defines the duration

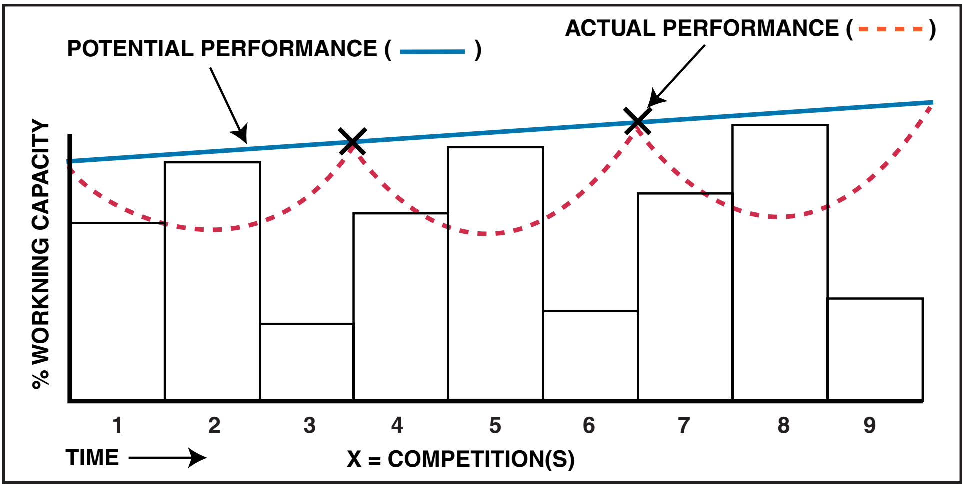


FIGURE 1.20—Actual and potential performance

of the base period. Mature athletes should normally undertake two athletic seasons and at least two weeks of post-season recovery, but young athletes should normally undertake a post-season recovery period of at least one month. During the early part of the base period athletes will be attempting to increase their training volume. Normally, the quality of the work is low, and so they will have no difficulty with training for three to four weeks before taking a worthwhile break. However, as athletes undertake high quality base work they will require a break after only two to three weeks of hard training. As shown in Figure 1.21, a meso-cycle structure of progressive loading over succeeding weeks is usually ideal during the base period.

The hill period is often reduced to a training emphasis during the cross-country season. However, middle distance runners often conduct more highly structured hill repetition work in preparation for the outdoor track and field season. In this regard, the hill period could include two to three weeks of progressive work, followed by a worthwhile break, thus determining a hill period of three to four weeks. Alternately, a five-to-six-week hill period could be broken up into two meso-cycles—each including two workweeks followed by a worthwhile break, as shown in Figure 1.22.

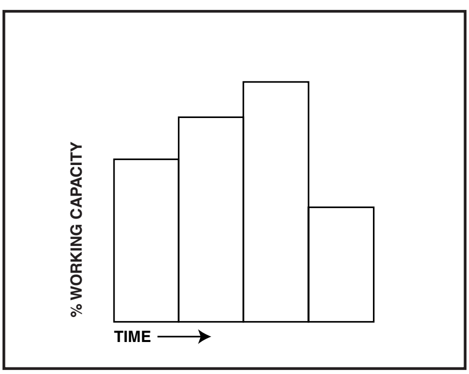


FIGURE 1.21

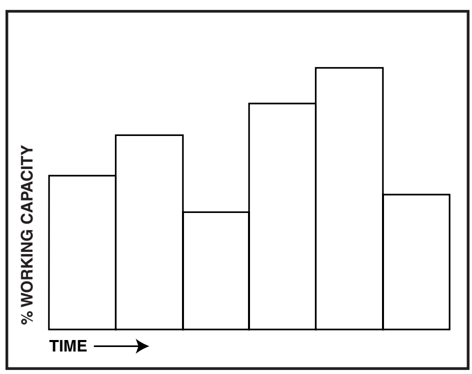


FIGURE 1.22

Again, always conclude a given training period with a worthwhile break that ends with a time-trial, or performance. This practice will:

- Consolidate and stabilize previous work
- Serve as a check upon athletic development
- Permit athletes to enter a new training period fully refreshed

The sharpening period incorporates especially demanding interval and repetition training. Also, athletes normally begin to compete more frequently during the sharpening period. Unfortunately, many high school and college athletes might then find themselves competing far too often. Given the effects of anaerobic work on the metabolism, the sharpening period is the most stressful. Normally, the length of the sharpening period is limited to three to four weeks. In order to realize optimal results, female distance runners and young male athletes (who enjoy less aerobic ability than mature male athletes) often only require three weeks of sharpening work. Mature athletes intending to compete in 10-to-12-kilometer cross-country races sometimes also enjoy optimal results with only three weeks of sharpening work. However, mature male and female athletes normally achieve optimal results with a sharpening period of four weeks. Arthur Lydiard arrived at this realization by years of experimentation, and the best evidence from exercise physiologists and other coaches also support the discovery: The human body does not require more than approximately four weeks of sharpening work. When athletes exceed that duration, they often waste valuable time and energy, and the results prove counterproductive to a successful outcome.

During the sharpening period, athletes should not attempt four weeks of intensive training without taking a worthwhile break. Accordingly, the sharpening period is divided into two meso-cycles. A worthwhile break should be introduced approximately seven to 10 days into the sharpening period after completing the early progression of quality interval work. The first worthwhile break normally extends seven to 10 days, and then concludes with a competition in the main race event. After completing the early interval work and taking a worthwhile break to freshen up, athletes should be already coming into a respectable level of competitive fitness. This is the best time, and normally should be the only time, that athletes compete in their main race event during the sharpening period. Because the later repetition workouts can be tailored to eliminate any areas of weakness, it is important to obtain a clear picture regarding the athletes' fitness and performance in the main race event. In addition, given the rebound of energy that accompanies the worthwhile break, athletes will be better able to conduct the repetition workouts during the second seven-to-10-day meso-cycle of the sharpening period.

A meso-cycle model characterized by progressively increased loading best corresponds to the pattern of response and training requirements for athletes during the early part of the sharpening period. Accordingly, the training load can and should be increased over the first seven to 10 days of the sharpening period prior to taking the worthwhile break. However, during the second sharpening period, a meso-cycle model characterized by declining loading best corresponds

to the pattern of response and training requirements for athletes during the more stressful repetition workouts. The worthwhile break that follows the second seven-to-10-day meso-cycle then simultaneously comprises the beginning of the peak period, and in particular, the nine-to-10-day ascent (or so-called taper) to the plateau of peak performance which will then last approximately two to three weeks. This meso-cycle model of acquisition for the sharpening period is illustrated in Figure 1.23.

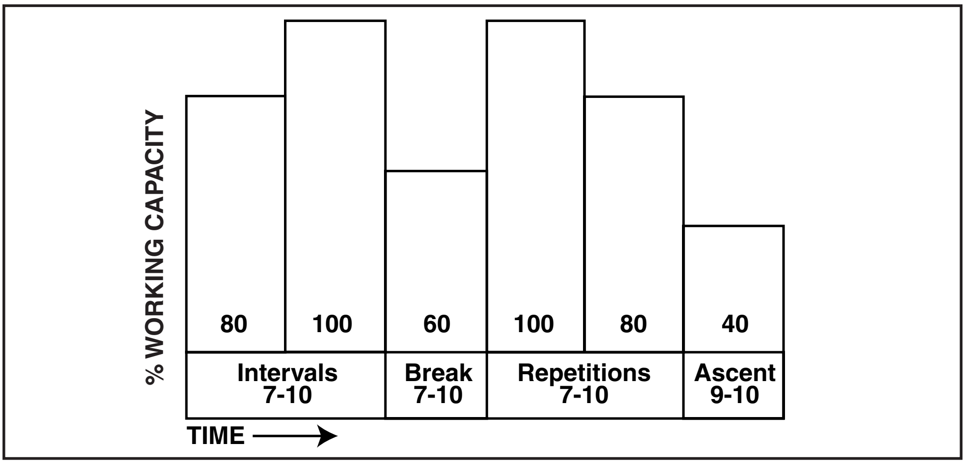


FIGURE 1.23—Meso-cycle structure of the sharpening period

Once the peak period begins, athletes normally do not undertake demanding acquisitive training efforts. For the most part, athletes essentially time trial, race and recover. However, three distinct types of peak periods should be discussed. A short peak period normally begins with a nine-to-10-day worthwhile break that simultaneously comprises the ascent or taper to a plateau of peak performance that will then last two to three weeks. Relatively few athletes desire to maintain race fitness beyond the normal two-to-three-week duration of the plateau of peak performance associated with a short peak period. However, sometimes important championship or qualifying competitions are more widely separated.

The plateau of peak performance can be extended beyond two to three weeks by reintroducing a delicate prescription of regenerative or stabilizing work, but this requires a relatively high level of sophistication. This more complex type of peak period is known as an extended peak period. For example, collegiate conference championships sometimes precede the national championships by several weeks. Accordingly, some maintenance or stabilizing training efforts can then be done to bridge the gap and extend the plateau of peak performance. In this case, athletes could perform one or more select workouts previously conducted during the athletic season. However, the effort of these workouts should be reduced relative to those conducted previously.

Occasionally, qualifying meets come one or more months prior to a major championship. For example, high school athletes might peak for their state cross-country championships, but then compete one or more weeks later in regional championships, and then again one or more weeks later in the national

championship. Athletes face this same situation if they compete in the USATF National Championships in mid-June or July, and then compete in the World Championships or Olympic Games in August or September. Often, athletes qualifying for international competition in the USATF National Championships, later fail to perform well in major international competitions in August or September. If and when athletes dash off to race in Europe immediately after the USATF National Championship, they could lose substantial fitness before the World Championships or Olympic Games. Therefore, they need to conduct a multiple peak period. In this regard, they would undertake at least one acquisitive or regenerative meso-cycle (including base and strength work), then conduct sufficient sharpening work to bring them back into a competitive level of fitness prior to re-ascending to the second plateau of peak performance for the World Championships or Olympic Games.

A post-season recovery period should be taken after the peak period. Mature athletes should normally take at least two weeks of post-season recovery. Since demanding training tends to suppress maturation, young athletes should take at least four weeks of post-season recovery. If necessary, more post-season recovery should be taken by the athletes to clear up any possible injuries and restore their enthusiasm.

MACRO-CYCLES: PLANNING THE ATHLETIC SEASON

Three phases of training activity characterize athletic development. How do these three phases relate to the training undertaken by runners during an athletic season?

Acquisition corresponds to the preparatory phase in which athletes conduct general and specific conditioning work in order to improve their athletic performance potential. This phase includes the workweeks conducted during the base, hill, and sharpening periods. An acquisitive training load, micro-cycle, or meso-cycle is intended to actively raise the performance potential of athletes and often includes ground-breaking or novel workouts.

Consolidation corresponds to the competitive phase in which athletes stabilize and realize their performance potential via actual performance. This phase includes the worthwhile breaks taken during the athletic season, but primarily corresponds to the peak period. A stabilizing training load, micro-cycle, or meso-cycle is designed to maintain and consolidate fitness. Accordingly, selected workouts previously conducted during the athletic season can be repeated with some decrease in the training effort. In contrast, a regenerative training load, micro-cycle, or meso-cycle is designed to more substantially rebuild certain aspects of fitness. It normally includes a brief recap of activity assumed during one or more distinct training periods (such as the base, hill, sharpening, or peak periods), and the work will be conducted in like-sequence. Stabilizing or regenerative work is sometimes performed during the peak period in order to extend its duration.

Decline corresponds to the transitional phase—required to prevent habituation to the training and the onset of residual or chronic fatigue. It also permits

delayed transformation and thus allows improvement of performance potential between two successive athletic seasons. The decline or transitional phase is associated with the post-season recovery period. Figure 1.24 shows a prudent modulation of quantity, quality, and performance over the various training periods.

PERIOD	QUANTITY	QUALITY	PERFORMANCE
BASE	80-90%	10-20%	0-5%
HILL	60%	30%	10%
SHARP	40%	45%	15%
PEAK	20%	35%	45%

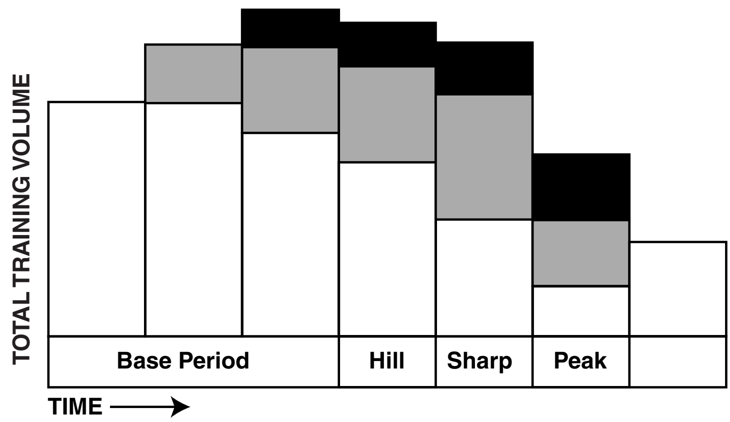


FIGURE 1.24

Macro-Cycles: Planning the Structure of the Athletic Season

Based on this framework, you can now construct a detailed plan for an entire athletic season. To make the plan, begin with a tentative competitive schedule and a large desk calendar. Then prepare to work backwards! Cut and tape the calendar months together into a continuous scroll encompassing the entire athletic season. It will help if you denote the major peak competition of the season with a zero, and then number the calendar backwards in the manner of a countdown. After you establish the first athletic competition to fall within the projected two-to-three-week plateau of peak performance:

- Count back 9 to 10 days to establish the beginning of the peak period, thus allowing for the worthwhile break constituting the ascent, or so-called “taper” leading to the plateau of peak performance
- Count back approximately 28 days or 4 weeks from that point to define the beginning of the sharpening period
- Count back approximately 4 to 6 weeks, depending on which of the meso-cycle models has been adopted, to define the beginning of the hill period
- Anything previous would then constitute the base period

Once the general structure, length, and placement of the training periods has been determined, they can be color-coded on the calendar with a highlighter. Then, working backwards from the peak period, select three to four competitions (each separated by at least 10 to 21 days) as possible targets for performance in the main race event. These contests should become more competitive as the season progresses. Preferably, any other competitions during the season should be over-distance or under-distance relative to the main race event. The selection regarding over-distance versus under-distance competitions should be determined by what will best balance the individual athlete's fitness, given the composition of the larger training program. Generally, runners should compete more frequently in their weaker off-distance event.

Again, athletes should only compete in the main race event at the end of an acquisitive training meso-cycle, after taking a seven-to-14-day worthwhile break. Normally, runners are best prepared for the main race event by assuming a preceding time-trial or under-distance race. With mature athletes in a high level of fitness, best results are generally obtained with the conduct of a time trial or under-distance race three to four days before the main event, within a worthwhile break lasting seven to 10 days. For high school or collegiate athletes, best results are normally provided by a time trial or race four to five days before the main event, within a worthwhile break lasting nine to 10 days. However, this latter scenario could also benefit mature athletes when substantial travel enters the equation. A time trial or competition between 300 to 600 meters is generally advisable for specialists at 800 meters; 600 to 1,200 meters for specialists at 1,500 meters; 1,000 to 1,500 meters for specialists at 3,000 meters; 1,500 to 2,000 meters for specialists at 5,000 meters; and 2,000 to 3,000 meters for specialists at 10,000 meters.

The training and racing schedule should be created to facilitate the best competitive results during the peak period. Do not simply take the same old conference schedule that has been handed down year after year as if it were the Ten Commandments, and then plan the current athletic season so as to neatly fit into the mold. If you do, the results will likely be the same as with every other coach or athlete who has used it. Think outside the prevailing box, or conventional un-wisdom. Apply your knowledge, experience and creativity when planning a training schedule for the athletic season. Remember, the duration of the meso-cycles should decrease and their frequency should increase as the quality of the training improves during the season.

This procedure will determine both the number and structure of the meso-cycles within the macro-cycle, or athletic season. You might then number and indicate the structure of the meso-cycles along the edge of the calendar. Now you can plan the workouts for each day of the athletic season! Obviously, circumstances may lead you to modify the schedule, but you will literally be able to see (and thus, better judge) the effect of any adjustment on the balance of the season's training. And sometimes an athletic season does happen to unfold according to plan without making a significant change. The planning process may take the better part of one or more evenings for an experienced coach or athlete. Creating a plan for an athletic season is much like solving a difficult jigsaw puzzle.

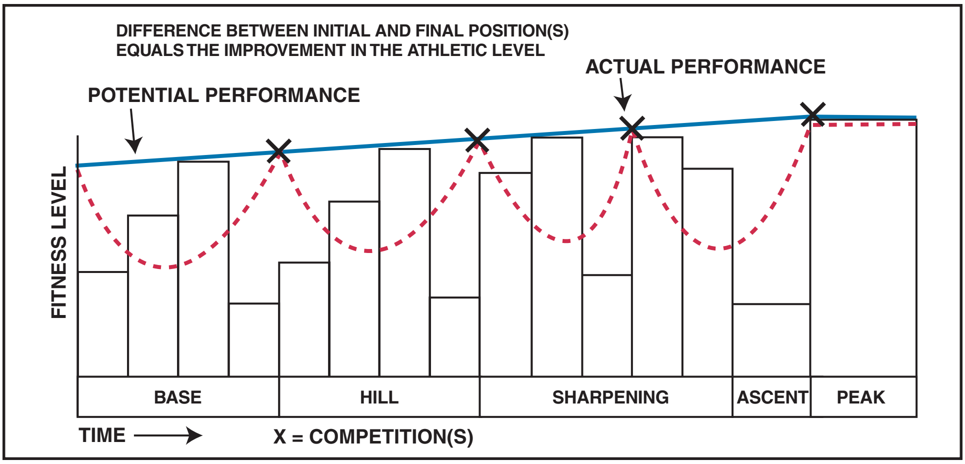


FIGURE 1.25—Macro-cycle, or athletic season

Completing the seasonal plan is well worth the time and effort. Coaches will be able to use the final product to educate athletes, and intelligently answer questions concerning what they are doing, and why. The tyrannical "do this" and "do that" coaching style can be abandoned, and instead, the style of an educator can be adopted. Coaches might even hold a class and teach the subject of athletic training during the first few days of organized team practice. Athletes can then "learn by doing," and actually plan their individual training schedules for the athletic season. The two-way communication afforded by a mature coach-athlete relationship will enhance the quality of the decision-making process, and thus, competitive results. An additional reward will be the confidence and enthusiasm generated amongst the athletes. A direct causal connection exists between enlightenment, self-directed physical and mental activity, and excellence. The sooner athletes acquire the knowledge, experience and confidence required to plan their own training and assume responsibility for their athletic destiny, the better will be the results both on and off the field (Cerutty, 1964, 1967, and Harre, 1982).

Figure 1.25 illustrates a macro-cycle model that integrates the various training periods and meso-cycles. The left axis indicates the athlete's level of fitness, and the bar graphs (indicating percent working capacity) represent the workload assumed by the athlete. The difference between the initial fitness level and the highest fitness level indicates the amount of improvement in the athlete's potential and actual performance level over the athletic season. The slope of the blue line of performance potential indicates the rate of change in improvement over the athletic season. The dashed arcuate line of actual performance illustrates both the suppression of performance potential by hard work, and the subsequent dramatic rebound by the end of each worthwhile break. The X symbols indicate primary competitions, and should be placed at the end of the worthwhile breaks, when the potential performance and actual performance levels become equated, and their lines intersect.

Figure 1.26 shows a macro-cycle including a multiple peak-period for bridging the gap between the USATF National Track and Field Championship and a major international competition.

Date Pace and Goal Pace

How do you properly progress the date pace, goal pace and finishing speed during the macro-cycle or athletic season? At the beginning of the sharpening period the athlete should conduct quality work at goal pace for the main race event. Goal pace corresponds to the pace of the desired goal performance in the main race event during the peak period. Date pace work is normally conducted once a week during the base and hill periods to enable a gradual progression of physiological and biomechanical function, and to establish a sound foundation for later work at goal pace during the sharpening period (Dellinger, 1973). Normally date pace work should be incrementally reduced in quality from goal pace by 1 second per 400 meters in each meso-cycle preceding the sharpening period. Date pace work can also maintain or improve an athlete's running economy, and thereby facilitate high quality base and hill work. Finishing speed work is intended to advance or improve an athlete's closing speed over the last 400 meters of a race. The desired maximum closing speed over 100 or 200 meters constitutes goal finishing speed. This work is normally conducted as a brief series of controlled accelerations or repetitions no longer than 400 meters, and the athlete then takes full recovery periods. Finishing speed work can be progressed by .5 seconds / 200 meters in each meso-cycle leading up to the plateau of peak performance, thus enabling goal finishing speed and optimal performance to be achieved during the peak period.

Figure 1.27 shows an abstract prescription and progression of date pace, goal pace and goal finishing speed for an athletic season. It indicates the various training periods, as well as the structure of the meso-cycles and larger macro-cycle. The duration of the workweek and worthwhile break segments, and also the ascent and peak, are shown in days. The athlete's potential and actual performance levels are also indicated at any given point in time. Figure 1.27 has also been modified and left blank for use as a worksheet by coaches and athletes, and appears as Figure 4.3 in Chapter 4. The abbreviations main race event (MRE), over-distance event (ODE), and under-distance event (UDE) also appear, and their significance will be addressed.

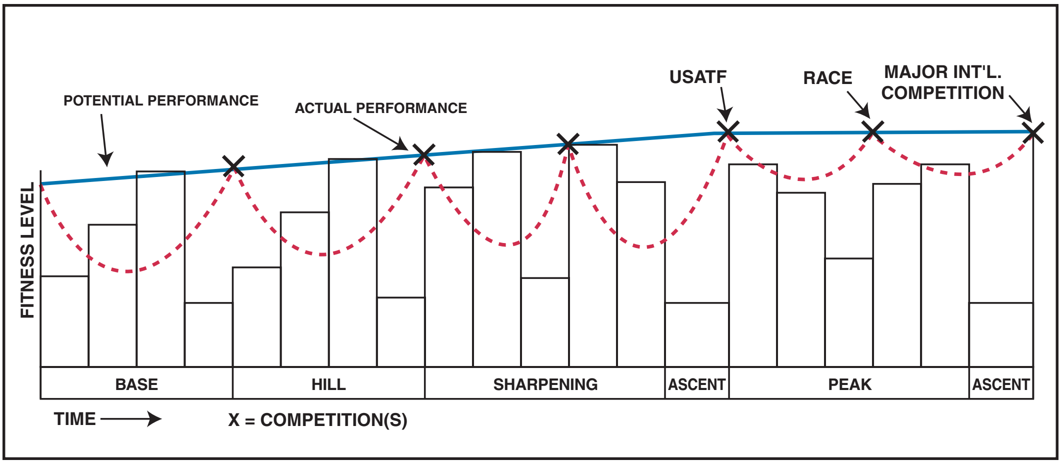


FIGURE 1.26—Extended athletic season for senior U.S. athletes

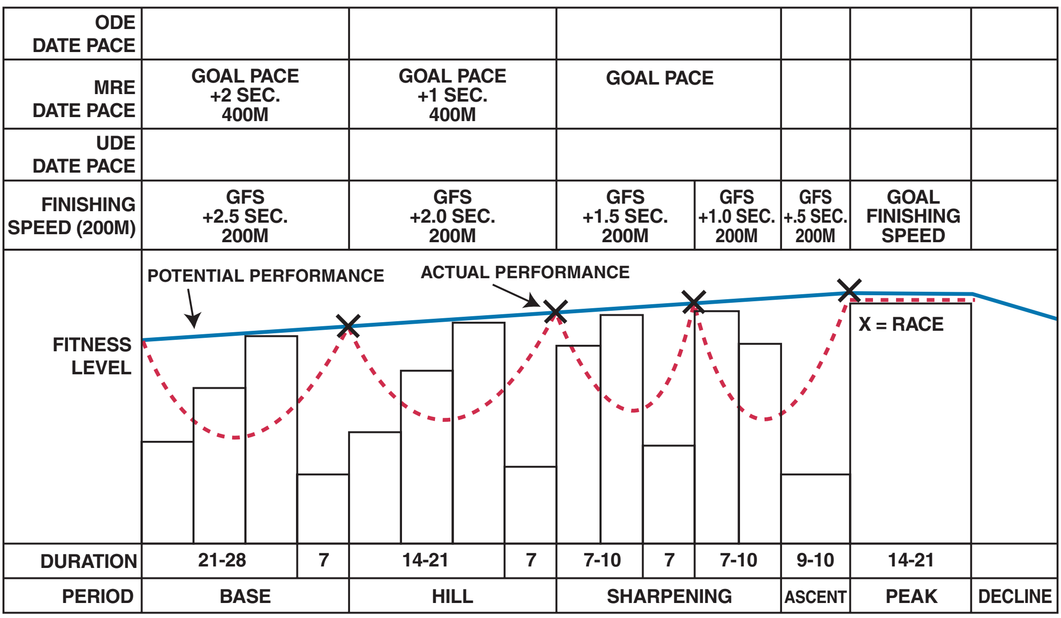


FIGURE 1.27—Date pace and finishing speed progressions

Figure 1.28 illustrates an athletic season model for a 1,500 meters performance of 3:42, corresponding roughly to a 4-minute mile. It indicates date pace, goal pace and also the potential and actual performance levels in the main race event (MRE), over-distance event (ODE) and under-distance event (UDE). Athletes will normally conduct several meso-cycles of base work, and only the last meso-cycle corresponding to the base period is shown in Figure 1.28. The illustrated base period meso-cycle could include approximately 21 days of demanding training in which the training load is gradually increased, then a worthwhile break lasting seven to 10 days. It would thus contain a maximum total duration of less than four weeks. A time trial or competition should be conducted at the end of the first worthwhile break, marking the conclusion of the base period and beginning of the hill period. Normally, an athlete with the potential to run a time of 3:42 in the 1,500 meters main race event (MRE) during the peak period will have an actual performance level of 3:54 at this time. The equivalent performance in the 800 meters under-distance event (UDE) is then approximately 1:54, and in the 5,000 meters over-distance event (ODE), about 14:18. These performances can be expected if an athlete elects to compete in an over-distance or under-distance event at this time. The over-distance performance is normally much easier to attain, since not enough sharpening work will have then been conducted to permit an equivalent performance over 800 meters (For determining equivalent performances, see Tables 4.8 and 4.9 in Chapter 4, and also, Daniels and Gilbert, 1979, and Daniels, 1998). The date pace work conducted for the main race event during the first meso-cycle would be 62 seconds/400 meters and a performance corresponding to that pace would be delivered at the end of this meso-cycle. Figure 1.28 also indicates the quality of date pace work corresponding to the over-distance and under-distance events, and also the athlete's finishing speed progression.

The next meso-cycle consists of 14 to 21 days of hill work followed by a worthwhile break lasting seven to 10 days, thus has a total duration of three to four weeks. The progression of date pace and finishing speed is also indicated. At the end of the hill period, the athlete should be capable of delivering a 3:50 performance in the 1,500 meters. The equivalent under-distance performance in the 800 meters is then approximately 1:52, and the equivalent over-distance performance in the 5,000 meters is about 14:05.

Again, the duration of the sharpening period should be limited to approximately four weeks or 28 days. The sharpening work is too demanding to be conducted in one continuous block of ever-increasing training loads. Instead, it should be divided into two meso-cycles. The first seven-to-10-day meso-cycle should have gradually increasing training loads, including interval training, and should be

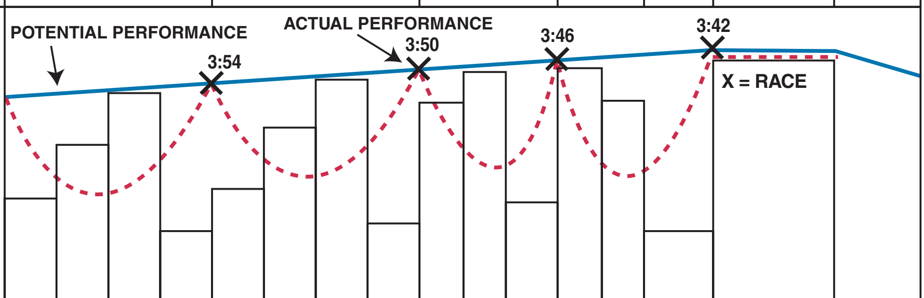
ODE: 5,000M DATE PACE FITNESS LEVEL	68 14:18		67 14:05		66 13:51				13:37	
MRE: 1,500M DATE PACE FITNESS LEVEL	62 3:54		61 3:50		60 3:46				3:42	
UDE: 800M DATE PACE FITNESS LEVEL	56 1:54		55 1:52		54 1:50				1:48	
FINISHING SPEED (200M)	25.0		24.5		24.0		23.5	23.0		
FITNESS LEVEL										
DURATION	21-28	7	14-21	7	7-10	7	7-10	9-10	14-21	
PERIOD	BASE		HILL		SHARPENING			ASCENT	PEAK	DECLINE

FIGURE 1.28—Schedule for a 1,500 meters performance of 3:42

followed by a worthwhile break of seven to 10 days. At the end of this worthwhile break, the athlete should be capable of delivering a 1,500 meters performance of 3:46. The equivalent under-distance performance in the 800 meters is then approximately 1:50, and the equivalent over-distance performance in the 5,000 meters is about 13:51. The second seven-to-10-day sharpening period meso-cycle then follows, and is characterized by repetition training and a decline in training loads. Afterwards, the next worthwhile break lasts between seven to 14 days, but nine to 10 days normally provides the best results. This worthwhile break permits the ascent to the plateau of peak performance, thus it can be viewed as part of the sharpening period or the beginning of the peak period. In this text, it will be treated as part of the peak period. Once upon the plateau of peak performance, the athlete will be able to deliver a 1,500-meter performance of 3:42 (roughly corresponding to a four-minute mile) in the targeted championship competition. The equivalent under-distance performance in the 800 meters is then 1:48, and the equivalent over-distance performance in the 5,000 meters is 13:37. This figure also shows the final progression of finishing speed work.

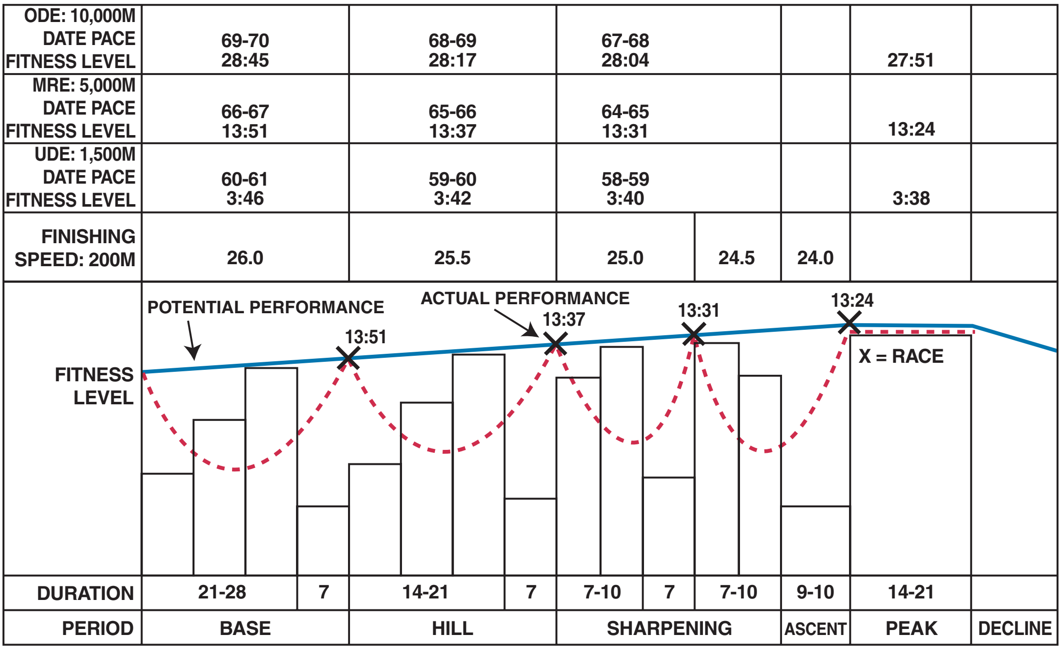


FIGURE 1.29—Schedule for a 5,000 meters performance of 13:24

Figure 1.29 illustrates a similar model of an athletic season for an athlete who would deliver a 5,000-meter performance of 13:24. Abstract finishing speed progressions for world class women and men in various events are shown in Table 1.2, and Table 1.3, respectively.

TRAINING PERIOD	800 METERS	1,500 METERS	3,000 METERS	5,000 METERS	10,000 METERS
BASE	26.0 5x150	27.0 5x200	28.0 5x200	29.0 5x200	30.0 5x200
HILL	25.5 5x100	26.5 5x150	27.5 5x200	28.5 5x200	29.5 5x200
SHARPENING PART 1	25.0 4x100	26.0 4x150	27.0 4x200	28.0 4x200	29.0 4x200
SHARPENING PART 2	24.5 4x60	25.5 4x100	26.5 4x150	27.5 4x200	28.5 4x200
ASCENT	24.0 3x60	25.0 3x100	26.0 3x150	27.0 3x200	28.0 3x200

TABLE 1.2—Finishing speed progression for world class women by event

TRAINING PERIOD	800 METERS	1,500 METERS	3,000 METERS	5,000 METERS	10,000 METERS
BASE	23.0 5x150	24.0 5x200	25.0 5x200	26.0 5x200	27.0 5x200
HILL	22.5 5x100	23.5 5x150	24.5 5x200	25.5 5x200	26.5 5x200
SHARPENING PART 1	22.0 4x100	23.0 4x150	24.0 4x200	25.0 4x200	26.0 4x200
SHARPENING PART 2	21.5 4x60	22.5 4x100	23.5 4x150	24.5 4x200	25.5 4x200
ASCENT	21.0 3x60	22.0 3x100	23.0 3x150	24.0 3x200	25.0 3x200

TABLE 1.3—Finishing speed progression for world class men by event

Figures 4.6 and 4.7 in Chapter 4 provide date pace and finishing speed progressions for performances of 4:38 and 4:00 in the 1,500 meters, corresponding to the athletic levels of high school girls and boys who would qualify for their state championships. In addition, Tables 4.2 and 4.4 provide finishing speed progressions for national caliber high school athletes.

MEGA-CYCLES: MULTIPLE YEAR DEVELOPMENT AND PEAKING SCENARIOS

How can multiple macro-cycles or athletic seasons be illustrated? What can be seen and understood by doing so? By illustrating a progression of macro-cycles or athletic seasons, a multi-year model of athletic development can be created. This is essential for properly planning how to develop and peak for a major competitive event held periodically, such as the Olympic Games.

Athletes normally complete an athletic season at a higher athletic level relative to the preceding season. This can be expected provided that runners train properly and athletic development takes place. The training and development that occurs during the course of an athletic season can be classified by one of three phases:

1. *Acquisition* corresponds to the preparatory phase, and includes the base, hill, and sharpening periods
2. *Consolidation* corresponds to the competitive phase, and in particular, the peak period
3. *Decline* corresponds to the transition phase, and is associated with the post-season recovery period

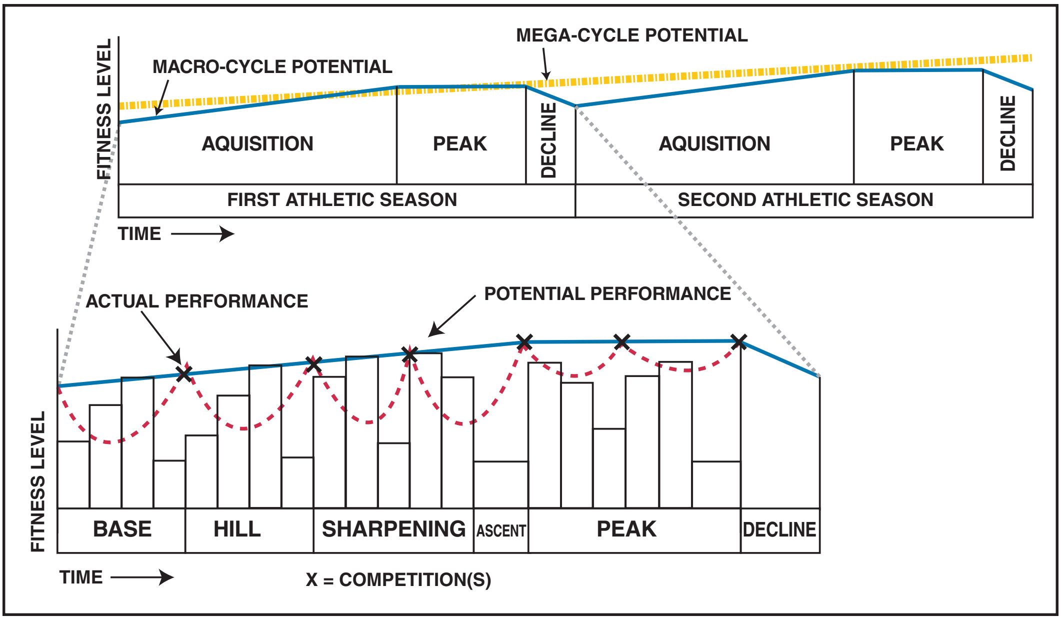


FIGURE 1.30—The Mega-Cycle model

In Figure 1.30, the yellow line supported by the crest of the larger macro-cycles or athletic seasons represents mega-cycle potential. This line indicates the direction and momentum of athletic development over a series of macro-cycles, or athletic seasons. The prefix “mega” has been used because it agrees with established vocabulary, and indicates thousands of training days, thus is true to scale. The slope of the ascending yellow line representing mega-cycle potential indicates the rate of change for the mega-cycle over months or years of training. Moreover, the projection of this line into the future represents potential future development, but also the prudent limits of acquisitive training and load tolerance over the next macro-cycle.

Acquisitive training efforts always suppress performance. For this reason athletes never see all of the development effected by the training within a given season. This is known as delayed transformation, and it is responsible for the continued improvement of performance potential realized during the decline or transition phase of training when athletes undertake post-season recovery (Harre, 1982). The continued positive slope of the yellow line representing mega-cycle performance potential during the post-season recovery period illustrates this phenomenon.

When runners attempt a too rapid Herculean acquisition effort within a given athletic season, they fail to reap the full benefit of improved performance during that particular season. The demanding acquisitive training efforts suppress athletic performance in much the same way as rapid physical maturation and

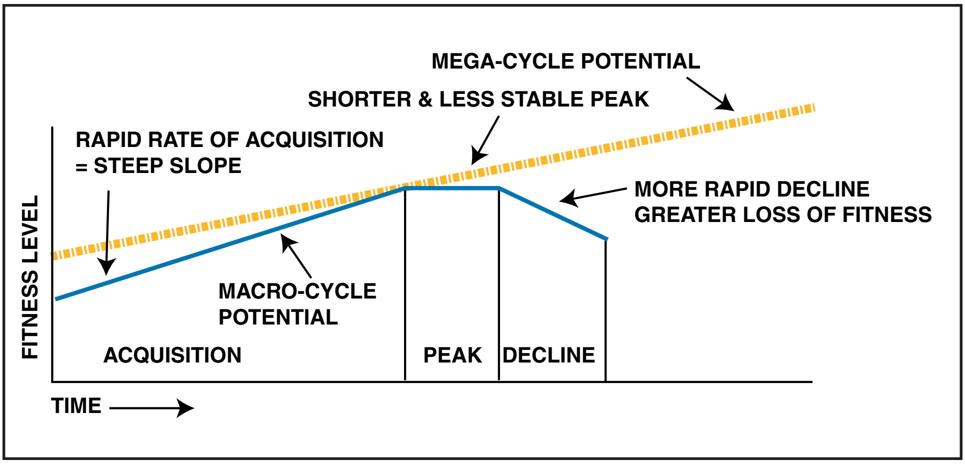


FIGURE 1.31

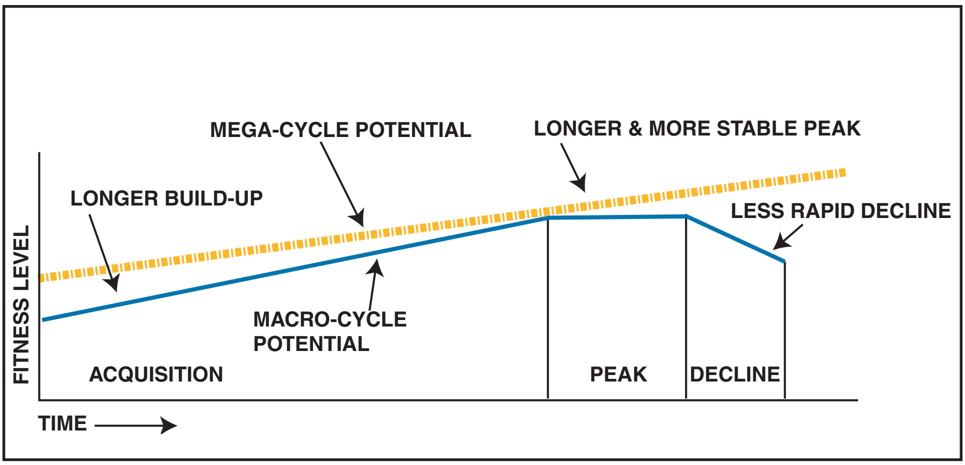


FIGURE 1.32

growth. This can be explained and graphically represented using the mega-cycle model. Remember, if athletes make an aggressive training effort during a macro-cycle, the slope of the blue line representing performance potential will be steep. This creates a wide gap between the yellow line representing mega-cycle—and the blue line representing macro-cycle performance potential. It also results in greater area between these two lines during all three stages of athletic development. This gap and area is proportional to the degree to which performance potential will be suppressed within that particular macro-cycle. Moreover, as shown in Figures 1.31 and 1.32, a rapid rate of acquisition normally results in a shorter, and less stable peak period, and also a longer period of decline relative to a longer and less aggressive training build-up.

Again, if athletes are aggressive with acquisitive training efforts over a given macro-cycle or athletic season, the blue line representing macro-cycle performance potential will be steep, thus reflecting rapid acquisition. The magnitude of the training loads will then necessitate more frequent meso-cycles, that is, if residual and chronic fatigue are to be avoided. Nevertheless, even with frequent meso-cycles, the heavy training loads inherently have a sharpening effect, thus accelerate the rate of reaching peak fitness, and shorten the effective duration of the athletic season. As a result, the athletes could peak too early and be on a downhill slope by the championship competition. Figure 1.33 illustrates this phenomenon by reproducing Figures 1.31 and 1.32 in a simplified form on the same set of axes.

Figure 1.33 also illustrates how a relatively long period of decline brought on by too aggressive a training program can also suppress future potential. As a result, there is a greater variance at the beginning of the next athletic season, as shown between the blue line representing macro-cycle potential, and the yellow line representing the mega-cycle potential. A longer, more stable build-up results in less suppression of performance potential and a longer, more stable peak. All things being equal, it also results in a shorter period of decline and less suppression of actual performance levels during the next athletic season.

Athletes who engage in Herculean acquisition efforts might perform quite well in an Olympic year, but perhaps then be outstanding a year later. The presence of preliminary heats and the focus upon competitive outcomes accounts, in part, for the quality of the performances delivered in the course of an Olympic Games. However, delayed transformation is one of the reasons why a surge of world records often takes place during non-Olympic years.

As shown in Figure 1.34, when the aim of the athletic season is to refine the product of previous acquisition with minimal suppression of athletic performance, the blue line indicating macro-cycle performance potential should have nearly the same slope as the yellow line representing mega-cycle performance potential. In this regard, a relatively long and gradual build-up during an athletic season is best.

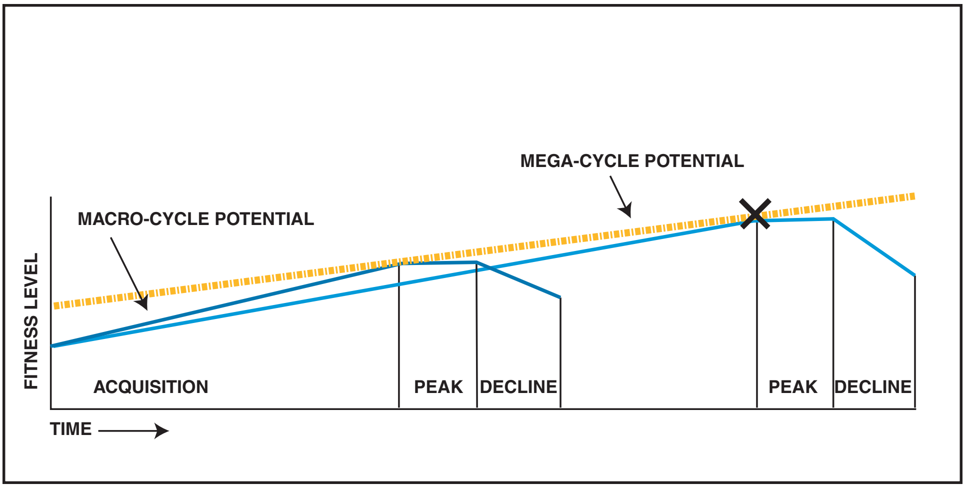


FIGURE 1.33

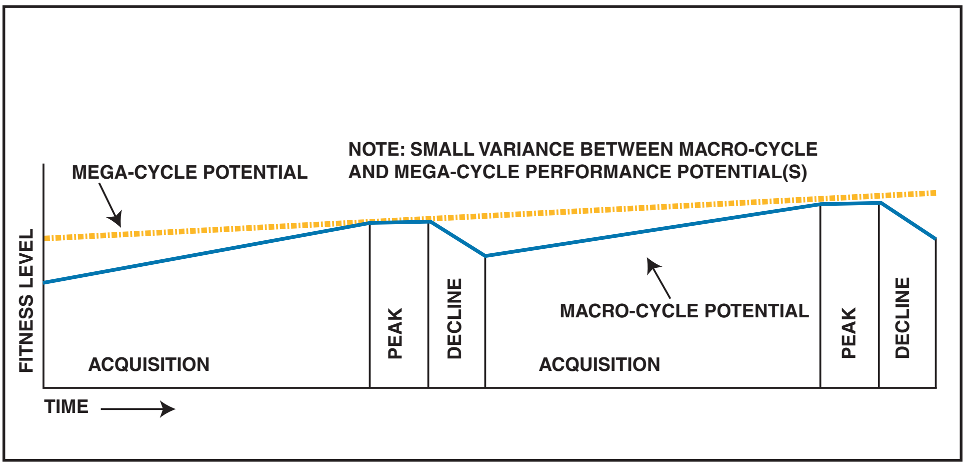


FIGURE 1.34

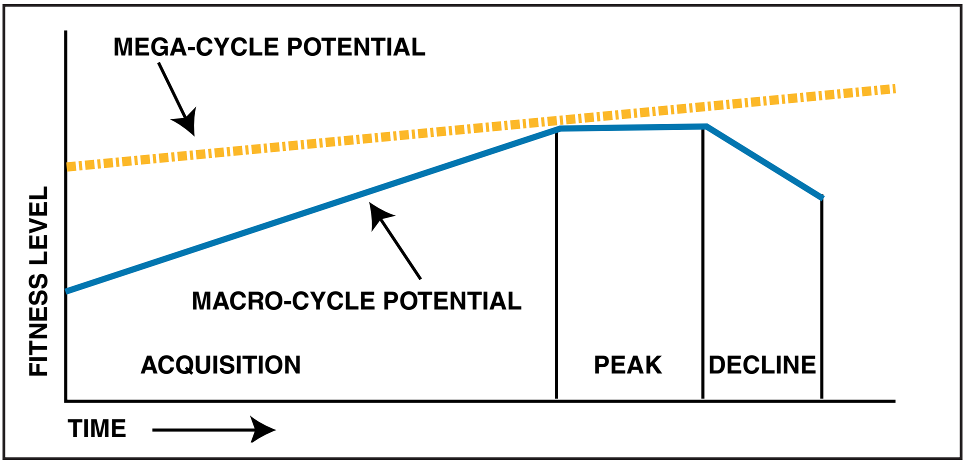


FIGURE 1.35—Young athlete

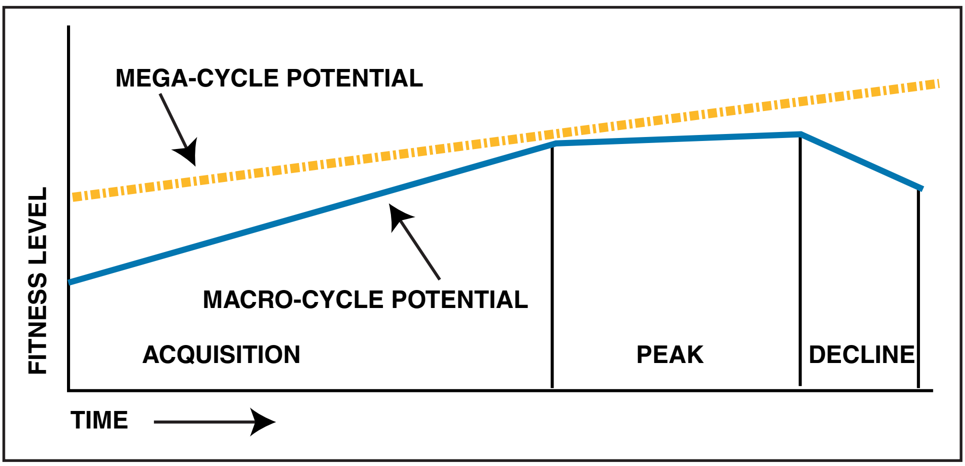


FIGURE 1.36—Mature athlete

As a result of many years of training, the mature athlete's peak period will lengthen. It also will be more stable, and support more frequent and higher quality performances. The required post-season recovery period will also normally be shorter. With a mature athlete, the slope of the peak performance plateau does not rapidly level off perpendicular to the left axis, but can continue to maintain a positive slope, thus reflecting their higher performance potential. In the case of mature athletes, the period of decline corresponding to post-season recovery will also have a less sudden drop-off and negative slope. Figures 1.35 and 1.36 represent this.

The better an athlete's preparation, the easier it will be to achieve a high athletic level during the peak period. Moreover, it will be easier to maintain athletic fitness and conduct an extended or multiple-peak period. Again, a multiple-peak period is required whenever athletes must peak in mid-June or July for the Olympic trials, and then again for the Olympic Games in late August or September.

Multiple Annual Athletic Seasons

The presence of two macro-cycles or athletic seasons within a calendar year will be identified as a bi-annual or two-season configuration, and three macro-cycles as a tri-annual or three-season configuration. Recognize that the amount of improvement in athletic fitness that is possible to achieve over a calendar year will normally be greater in a bi-annual configuration. Accordingly, the slope of the yellow mega-cycle line (representing performance potential) is steeper, and attains a higher value than in a tri-annual configuration. As shown in Figures 1.37 and 1.38, this happens simply because the bi-annual structure devotes more time to acquisition, whereas the tri-annual configuration sacrifices preparation for short-term competitive outcomes.

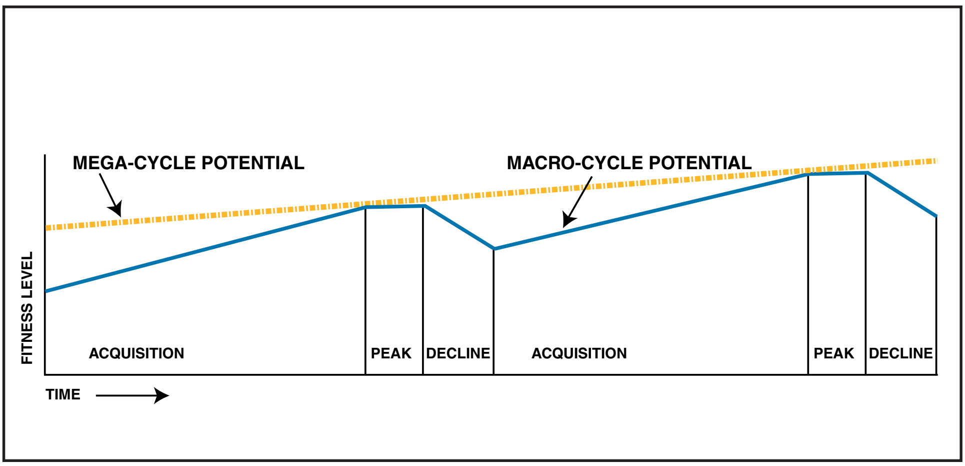


FIGURE 1.37—Bi-annual configuration

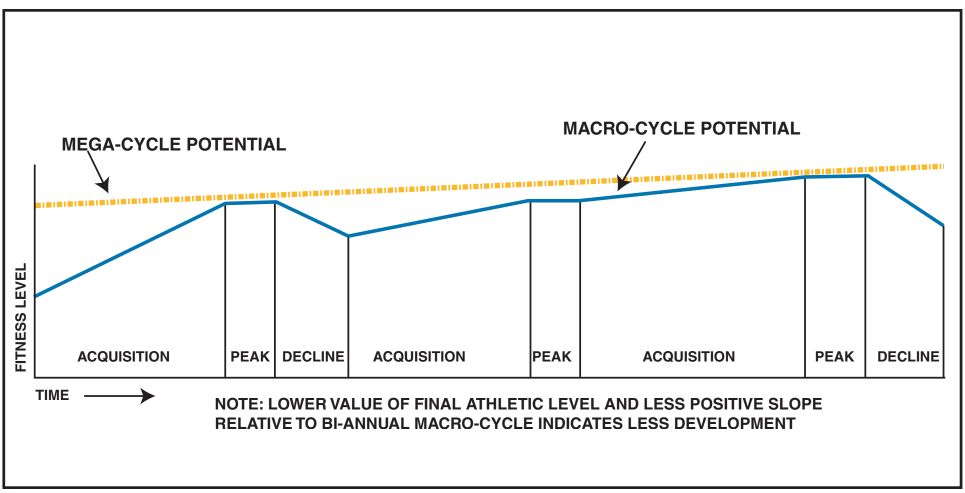
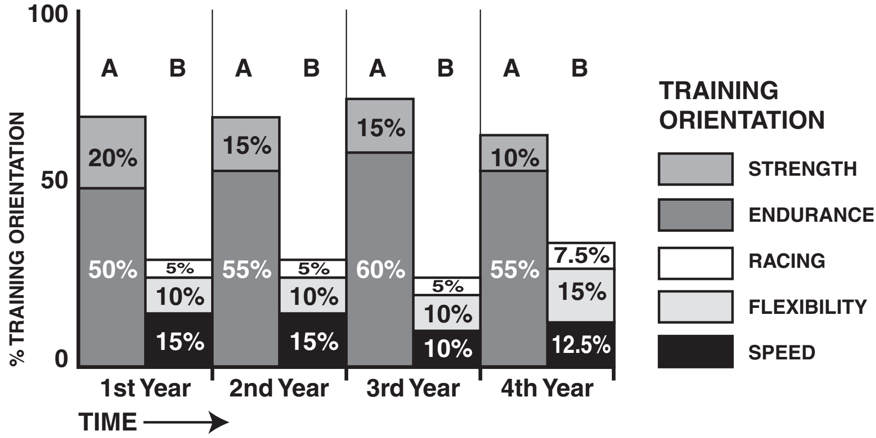


FIGURE 1.38—Tri-annual configuration



Relative percentage of general (A) and specific (B) athletic training of post-collegiate distance runners over four years.

FIGURE 1.39

In the United States, it would be commendable for the NCAA to address the year-round competition that collegiate distance runners contend with in cross-country, indoor, and outdoor track and field. No other group of collegiate athletes has a year-round competitive schedule. Developmentally, it does not make sense for distance runners to have three competitive seasons. This situation not only hurts their athletic development, but also their academic performance. The fact that distance runners tend to be fine students only serves to disguise the adverse impact of year-round athletic competition upon their academics. Institutions of higher learning have a responsibility to teach progressive educational practices and to demonstrate by example. For this reason, middle distance and distance runners should be limited to participation in only two of these three possible athletic seasons each year.

Peaking for the World Championships or Olympic Games

How can athletes optimize performance in the last year of a four-year developmental cycle? This is an important question for the collegiate coach, and also for post-collegiate athletes who aspire to competition in the Olympic Games. It is necessary to create sufficient vocabulary to describe scenarios for developing and peaking at the end of two, three, or four-year mega-cycles. A two-year developmental and peaking scenario will be referred to as biennial, and three or four year scenarios as triennial, and quadrennial mega-cycles, respectively.

In order to develop and peak in a quadrennial mega-cycle, athletes should progress the quantity and quality of acquisition efforts to optimal levels through the third year. This includes the progression of individual sharpening workouts that would be undertaken in the fourth year. But in the fourth year the training loads should level off, and in some cases, the volume and duration should actually be decreased. Further, athletes should work on their relative areas of weakness in order to balance their abilities in the over-distance versus under-

1st year	2nd year
3,000 meters	3,000 meters
1,500 meters	1,500 meters
3,000 meters	3,000 meters
5,000 meters	5,000 meters
5,000 meters USATF Prelims	10,000 meters USATF Final
5,000 meters USATF Final	3,000 meters Europe
3,000 meters Europe	5,000 meters Europe
5,000 meters Europe	10,000 meters Europe
3rd year	**4th year**
3,000 meters	3,000 meters
1,500 meters	1,500 meters
3,000 meters	5,000 meters
5,000 meters USATF Prelims	10,000 meters USATF Prelims
5,000 meters USATF Final	10,000 meters USATF Final
3,000 meters	3,000 meters
10,000 meters W.C. Prelims	10,000 meters Olympic Prelims
10,000 meters W.C. Final	10,000 meters Olympic Final

TABLE 1.4—Racing Schedule

distance events prior to the athletic season corresponding to the Olympic Games. For example, if athletes are weak on the 1,500 meters side of the 5,000 meters event, they should work to correct that deficiency. Athletes should then train towards their natural strength during the athletic season of the Olympic competition. In the fourth year, the quality of the sharpening workouts should be enhanced by placing greater emphasis upon race practice, that is, the ability to execute surges, breakaways and the finishing kick. In some cases, athletes should use competition to a greater degree, as a method of sharpening and advancing their athletic level. In sum, the aim should be to refine and polish the fruit of previous acquisitive work by placing greater emphasis on quality, technique and actual performance, as illustrated in Figure 1.39. Table 1.4 shows a progression regarding the number and type of competitions assumed by a U.S. distance runner who would move up from 5,000 meters to 10,000 meters over a four-year period in preparation for the Olympic Games.

Plan Ahead and Qualify Early

Athletes should normally obtain the qualifying time needed for the following year's major international competition, such as the World Championships or Olympic Games, during the preceding year's track and field season, after the stipulated qualifying date. They should not wait until they have qualified in their national championships (which are often tactical affairs conducted in poor weather conditions), and then suddenly realize that they also need to meet the international qualifying standard. If athletes put themselves in this situation, they could easily

lose control of their athletic destiny. For example, in order to make an attempt to obtain the standard, athletes might have to travel overseas and compete at an inopportune time. If and when the attempt succeeds—they may then have compromised optimal preparation for the major international competition. Athletes need to think ahead and intelligently plan their athletic careers with the big picture in mind.

This chapter merely describes and illustrates some of the laws of nature that relate to distance running. Coaches and athletes need to master this subject in order to effectively plan training schedules, but they must also prudently modify workouts in the light of circumstances. Planning a training schedule for a high school or collegiate team for an entire season can easily take one or two days, and an additional hour of preparation each day in order to individualize the workouts. Those who deny the merit of planning—pay the penalty. They fail to deliver their best performance at the right time and place.

When you look beyond the superficial differences in the vocabulary and training habits of successful coaches and athletes—you discover how much they actually have in common. For example, Bill Bowerman corresponded and visited with the accomplished coaches of his day, including Arthur Lydiard and Gosta Holmer. This exchange of information contributed to the development of the “Oregon system.” While it is true that “many roads lead to Rome,” they are all paved with the same stone.

In conclusion, coaches and athletes should appreciate the degree to which the nature and substance of athletic training is over-determined. There are reasons within reasons for what must be done, and they must all be consistent and harmonious with the desired end. The question of whether a particular workout is efficacious can only be answered by considering everything that has preceded and all that will follow in the training program. And here there must be unity and coherence. Everything enters the picture, everything matters, and everything is interrelated.

If you do not look at things on a large scale it will be difficult for you to master strategy.

—Miyamoto Musashi

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PHOTO 2.1—Arthur Lydiard of New Zealand captured at a press conference in 1964. From the title page of Arthur Lydiard and Garth Gilmour, *Run to the Top*, Auckland: Minerva, Ltd., 1967. Photo courtesy of Arthur Lydiard.

CHAPTER 2

THE BASE PERIOD

The base period is the first and longest of the five training periods of the athletic season, and its primary aim is to enhance aerobic ability. Improvements in aerobic ability result from adaptation to chronic training loads, thus take place over many months and years of training. Distance runners do not reach the peak of their development until well into their late twenties or thirties, and also must be willing to devote something on the order of ten years to achieve optimal results. A brief look at the relevant exercise physiology will demonstrate why the development of aerobic ability is so important for distance runners.

Exercise Physiology

The human body has three energy systems available for use in athletic performance:

- ATP-PC
- ATP-Lactic Acid
- ATP-Aerobic

Two of these energy systems are anaerobic, that is, they operate in the absence of oxygen, while one is aerobic, functioning in the presence of oxygen. Of the two anaerobic systems, the ATP-PC (Adenosine Triphosphate-Phosphocreatine) energy system dominates in explosive efforts up through 45 seconds, whereas the ATP-Lactic Acid system predominates in exhaustive efforts ranging from 45 seconds to three minutes. The aerobic pathway predominates beyond the temporal range of the ATP-Lactic Acid system, and is used almost exclusively in the marathon event. Table 2.1 provides an estimate regarding the predominant energy system used in various events.

The ATP-PC system provides a large power capacity, but is exhausted in 45 seconds duration. Its half-life—that is, the time required for it to reconstitute 50% of its capacity—is 20 seconds, 75% in 45 seconds, and 100% within 3 minutes duration (Kraemer, Fleck, 1982). Note that continuous slow jogging or running will postpone, if not completely thwart recovery of the ATP-PC system. Continuing intense efforts of relatively short duration, using a running-jog recovery, will then primarily stress the ATP-Lactic Acid energy system. Keep in mind which aspect of fitness the athlete is attempting to condition. If an athlete sets out to enhance their ATP-Lactic system, but walks or stands around between repetitions, then actually the ATP-PC system is recovering. For example, if an athlete runs reps of 200 meters at high speed with a relatively long walk recovery, then most of the training

Event	% Aerobic	% Anaerobic
400	15	85
800	35	65
1,500	60	40
3,000	85	15
5,000	90	10
10,000	95	5
Marathon	99	1

TABLE 2.1—Adapted from Sparks & Bjorklund, 1984

	Percentage of Fibers	
Athlete	Slow Twitch	Fast Twitch
Sprinter	24	76
Middle Distance	62	38
Marathon Runner	79	21
Cross-Country Skier	80	20
Untrained	53	47

TABLE 2.2—From Costill, Daniels, and Evans, et. al., 1976

session will utilize the ATP-PC system, whereas the use of a continuous jog recovery would stress the ATP-Lactic Acid energy system.

The third energy system is the aerobic pathway, also known as the Krebs Cycle, and it serves as the primary energy source for race events lasting over three minutes. Compared with the aerobic pathway, the anaerobic systems are extremely inefficient in their energy production. The ATP-PC system essentially constitutes a one-time-only source of energy in the early seconds of a race. In contrast, the ATP-Lactic system can be engaged whenever the athlete exceeds the capacity of the aerobic pathway to provide requisite energy. However, the ATP-Lactic Acid system produces a net of only two ATP's from available energy stores compared to 38 ATP's by the aerobic pathway, thus it is relatively inefficient on the order of 19:1!

That is one of the reasons why, once an athlete substantially begins to use the ATP-Lactic Acid system, energy reserves are quickly exhausted and metabolic by-products bring activity to a rapid halt. A recent study indicates that the metabolites phosphate and magnesium are responsible for muscle fatigue—not lactic acid (Posterino, Dutka, and Lamb, 2001). In addition, both anaerobic systems are limited to using carbohydrates as energy substrates, whereas the aerobic pathway can draw upon fatty acids and proteins. Female middle distance runners should not attempt to reduce weight by undertaking a non-carbohydrate diet and then engage in training or racing efforts that place demands on the ATP-

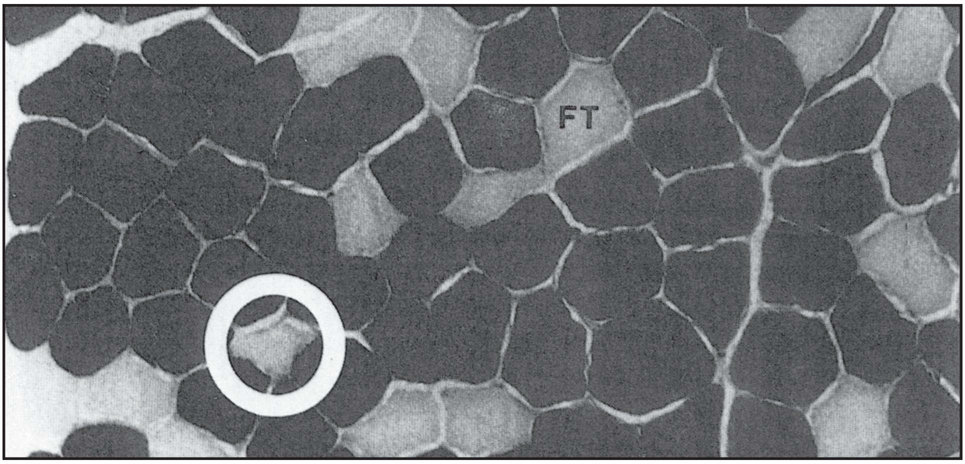

Photo 2.2—A microscopic view of Frank Shorter's leg muscle fiber type. The black fibers represent the slow twitch (type I) type, whereas the unstained cells are the fast twitch (FT, type II) fiber. Shorter's muscle was 80 percent slow twitch. From David L. Costill, *Inside Running*, Carmel, Indiana: The Cooper Press, LLP, 1986, page 5. Photo courtesy of David L. Costill.

Lactic Acid system, because they will become exhausted. The possession of superior aerobic ability also serves to enhance the efficiency of the anaerobic energy systems, because all the systems inhabit and utilize the same structure, and to some degree, the same arsenals. Further, the anaerobic systems depend upon the aerobic pathway for their recovery, so the athlete's aerobic ability serves as the limiting factor governing performance in distance running.

Many believe that an athlete's natural aerobic ability can be enhanced 25 to 35% over years of training. In response to chronic training loads, more capillaries will form, that is, their number as measured per square millimeter can increase 40% in a highly conditioned athlete, relative to a sedate individual (Åstrand and Rodahl, 1986). The mitochondria (the powerhouses of the cell) also greatly increase in number. The heart's stroke volume becomes larger, and it will then be able to pump more blood.

Further, we are all born with different ratios of one of two types of muscle fibers: slow twitch Type I muscle fibers (associated with endurance and aerobic ability), and fast twitch Type II muscle fibers (largely associated with explosive speed, power, and anaerobic ability). In addition, there are three different kinds of Type II muscle fibers: Type IIa is closely associated with the ATP-Lactic Acid system, Type IIb with the ATP-PC system, and Type IIc exhibits the ability to cross-train and assume many characteristics of the slow twitch Type I muscle fiber. Accordingly, specificity of training can, to some degree, influence the enzyme characteristics of various muscle fiber types so as to optimize performance in a given competitive event. Table 2.2 indicates the percentage of various muscle fiber types possessed by individuals competing in the different running events. Photo 2.2 shows a microscopic photograph of the leg muscle fiber type of Frank Shorter, the 1972 Olympic Gold Medalist in the marathon event.

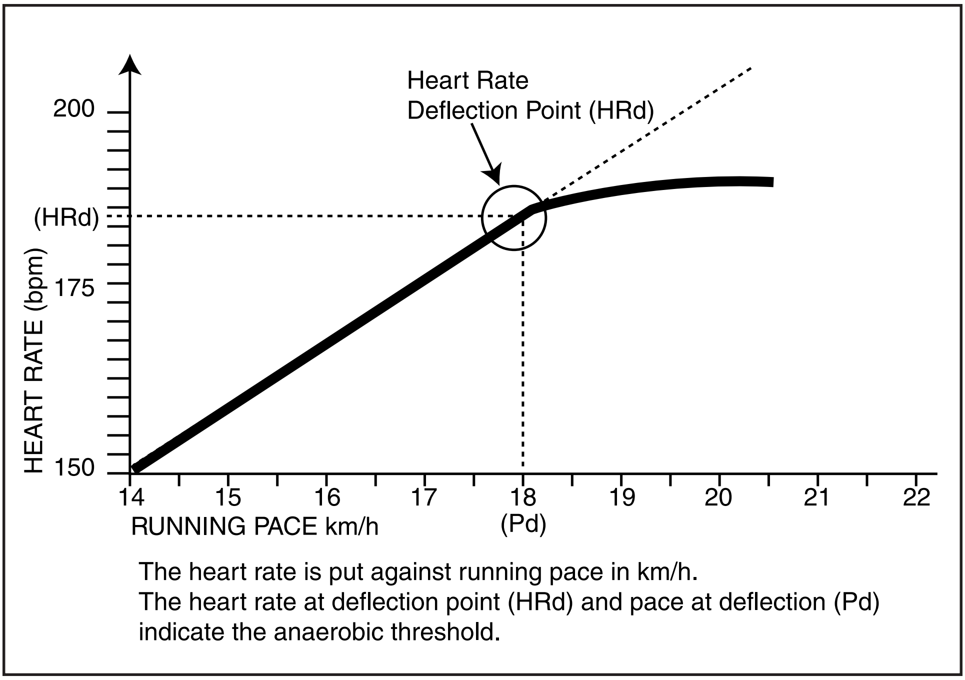

FIGURE 2.1—In well-trained athletes the heart rate (HR) in beats per minute (bpm) at the deflection point (HRd) is five to 20 (average 10.6) beats per minute lower than maximal heart rate. In untrained persons, the heart rate at the deflection point is 20 to 27 beats per minute lower than maximum heart rate (Adapted from Janssen, 1987).

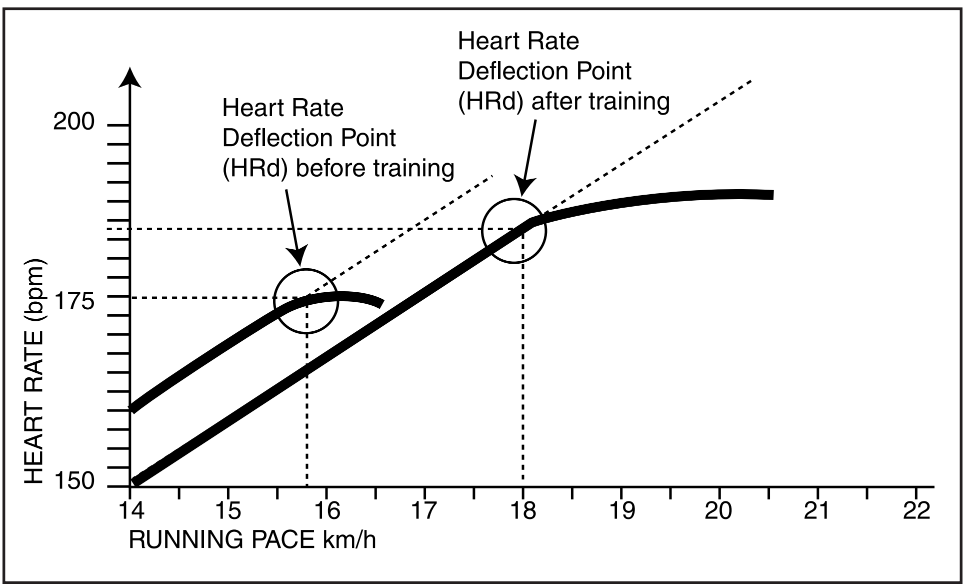

FIGURE 2.2 —Adapted from Janssen, 1987

Aerobic Training Theory

Again, an individual's aerobic ability is the primary limiting physiological factor in distance running performance. Once energy demands exceed the capacity of the aerobic pathway, exhaustion sets in geometrically. This exercise threshold is sometimes called the aerobic-anaerobic passing zone, or simply the anaerobic threshold. The heart rate of an athlete normally responds in a linear manner to increasing running speeds, that is, up to the point of the anaerobic threshold. Beyond this point, the heart rate will deviate from a linear progression and drop off, as shown in Figure 2.1.

As shown in Figure 2.2, with training and improved fitness, an athlete will be able to maintain a higher pulse rate and working level, and conversely, will be able to perform sub-maximal training loads at a lower heart rate than previously. Figure 2.3 shows one possible relationship between an elite runner's anaerobic threshold, running pace, and lactate production.

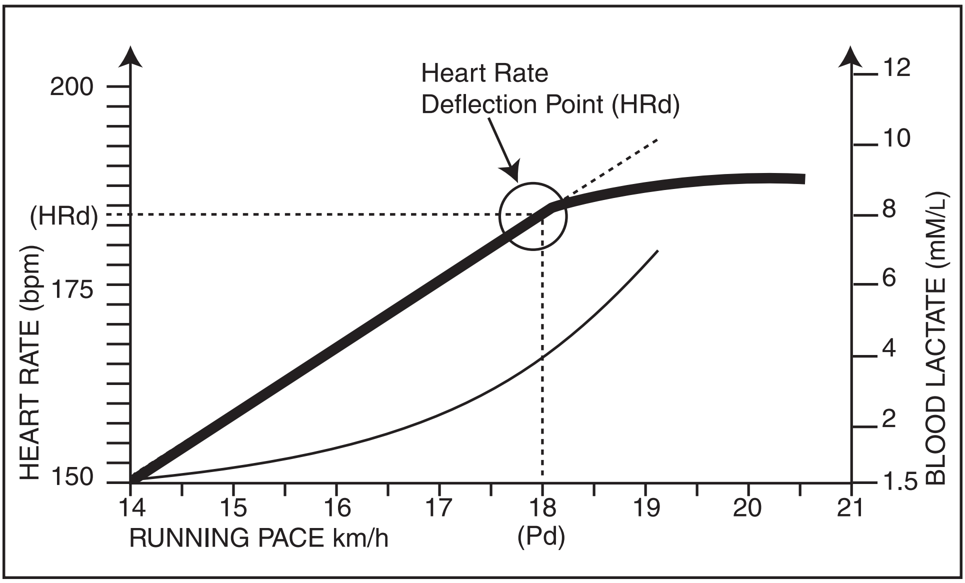

FIGURE 2.3—Adapted by permission from T. Noakes, 1991, *Lore of Running*, 3rd Ed., Champaign, IL: Human Kinetics, page 95.

The anaerobic threshold generally corresponds to a blood lactate level of approximately 4mM/liter. However, as fitness improves, the athlete will be able to run at higher continuous speeds with lower levels of lactate production, and will then cross the 4mM/liter anaerobic threshold when moving at higher speeds than before, as shown in Figure 2.4. Different training efforts can be associated with specific ranges of exhibited heart rate and lactate production, as shown in Figure 2.5. More specifically, Figure 2.6 shows the relationship between training effort, intensity, heart rate, blood lactate accumulation, and training activity.

See again Table 1.1, which provides a general guideline for relatively fit young athletes concerning the relationship between training effort, exercise heart rate, and VO_2 maximum. Our bodies can utilize fatty acids (primarily intra-muscular triglycerides), carbohydrates, or proteins as energy sources during exercise. Given low intensity exercise, runners use a high relative percentage of fatty acids as an energy source. However, the fatty acid metabolism is relatively slow and it cannot meet sudden high-intensity energy demands. In contrast, carbohydrates can satisfy relatively sudden high-intensity energy demands, but the human body can only store enough carbohydrates for about 90 minutes of high-intensity aerobic effort. When athletes function anaerobically, using the ATP-lactic acid energy system, they can exhaust the available carbohydrate stores in less than two minutes.

The brain can only use carbohydrates as an energy source, so when glycogen or carbohydrate stores are extremely low, an individual's mental concentration can be impaired. When high school or college students study intensively for final

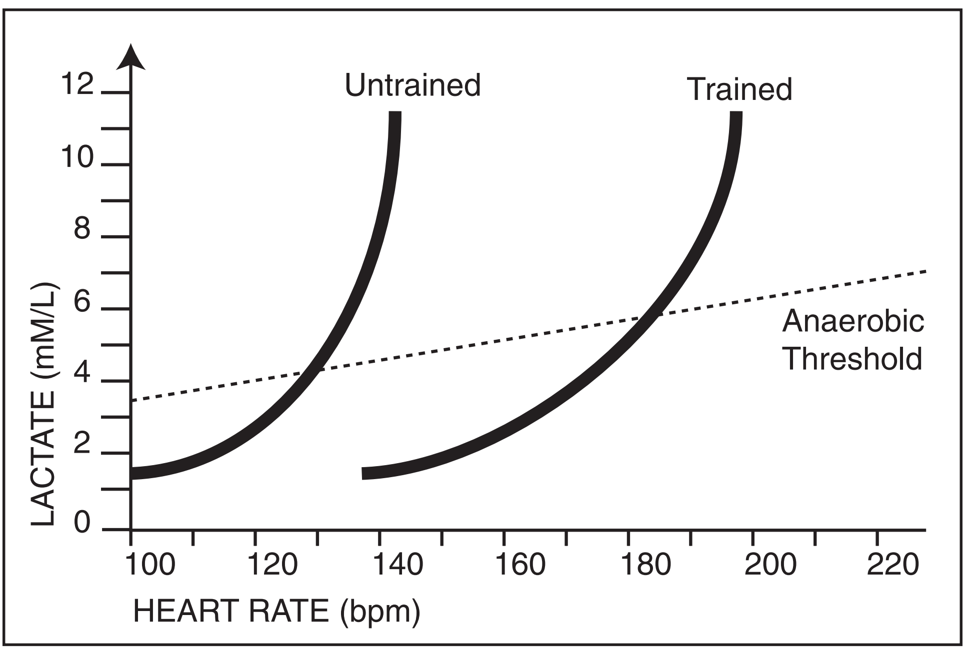

FIGURE 2.4—Adapted from Janssen, 1987

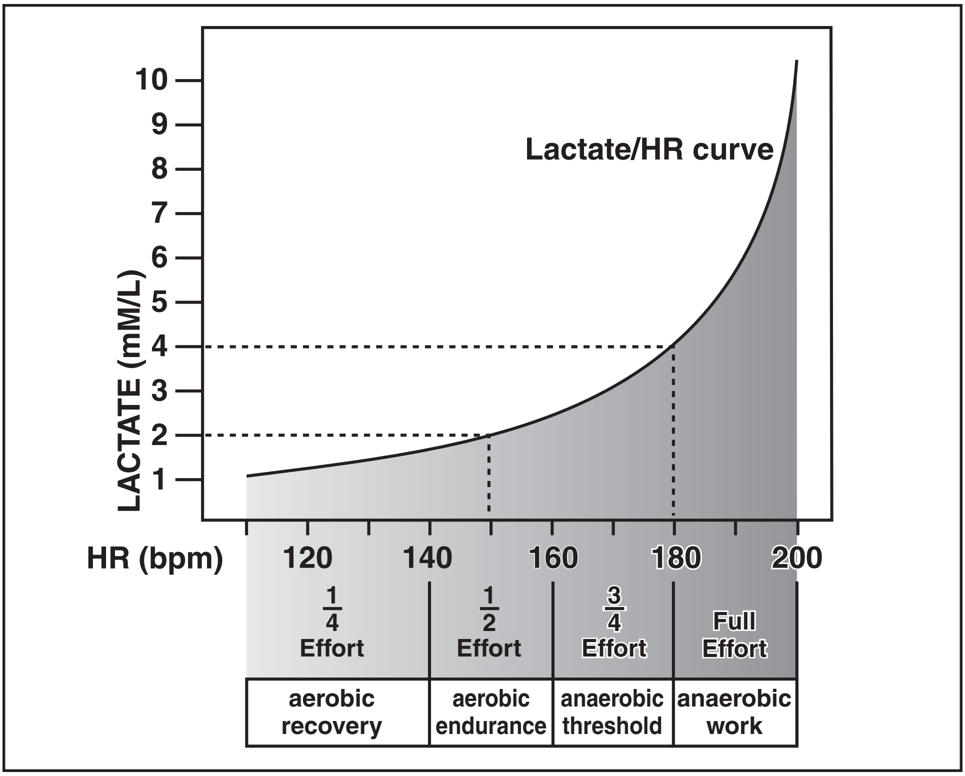

FIGURE 2.5—Adapted From Janssen, 1987

$\frac{1}{4}$ EFFORT	$\frac{1}{2}$ EFFORT
• Low Intensity Effort • Heart Rate 100 - 140 bpm • Lactate 1 - 1.5 mM/L • Passive Recovery • Easy Recovery • Active Recovery • Long Run, as Extensive Endurance Work	• Moderate Intensity Effort • Heart Rate 140 - 160 bpm • Lactate 1.5 - 2 mM/L • Active Recovery • Extensive Fartlek • Long Run, as Intensive Endurance Work (e.g., preparation for marathon)
$\frac{3}{4}$ EFFORT	**FULL EFFORT**
• High and Submaximum Intensity Effort • Heart Rate 160 - 180 bpm • Lactate 2 - 4 mM/L • Steady State Runs • Anaerobic Threshold Steady State Runs • Intensive Fartlek • Extensive Intervals • Extensive Repetitions • Early Date Pace Work • Early Finishing Speed Work	• Maximum Intensity Effort • Heart Rate 180 - 200 bpm • Lactate 4+ mM/L • Races • Time Trials • Intensive Intervals • Intensive Repetitions • Later Date Pace Work • Later Finishing Speed Work

FIGURE 2.6

exams, the depletion of carbohydrate stores is similar to what occurs during a 3/4-effort workout. Accordingly, it is prudent to adjust the training program during “finals week” and encourage athletes to consume sufficient carbohydrates.

Normally, proteins are not greatly used as an energy source during exercise. If and when this does happen, as it can during the marathon, an athlete’s legs will be slow to recover. And it generally takes at least seven to 14 days for an athlete to recover from competition in the 10,000 meters. Sometimes the presence of bad breath can indicate that an athlete has consumed muscle tissue protein during hard exercise.

In distance running, an important adaptation concerns the enhanced ability to use fatty acids as an energy source, thus sparing the more limited carbohydrate stores. A fitter athlete can use fatty acids as an energy source to a greater degree during a race, thus preserving a greater portion of available carbohydrate stores for executing surges, breakaways, and the finishing kick. Figure 2.7 illustrates this adaptation with respect to fatty acid utilization.

Of course, the enemy of adaptation and enhancement of an individual’s aerobic ability is father time. Maximum heart rate decreases with age. To make an approximation, take the maximum heart rate of 220 bpm, and then subtract the individual’s age in order to predict their maximum heart rate, as shown in Figure 2.8.

Steady-state Distance Runs

What is the most efficient way to improve our aerobic ability? Performing quality work near the anaerobic threshold enables high training loads to be sustained for a relatively long duration. The state of equilibrium achieved near the anaerobic threshold is commonly known as an individual’s steady state. Highly conditioned athletes will commonly perform at 86 to 88% of their VO_2 maximum for one hour, or approximately ten miles, while running at their steady-state pace (Daniels, 1999). So when athletes perform a steady-state run are they actually functioning below, within, or above the anaerobic threshold? The answer can be any of the above, depending on the individual and the particular circumstances. Athletes tend to intuitively optimize their performance in the steady-state run based on their limiting physiological factors on a given day. Some days the limiting factor could be that they had too little for lunch, and are low on carbohydrates. However, it is probably more accurate to say that an athlete performs at the “proton threshold,” that is, at the limit of the body’s ability to remove and buffer the acidity associated with blood lactate. Once the blood pH drops below 7.0, the enzyme functions and biochemistry required for continued exercise are quickly rendered inoperable (Newsholme, 1983). This variable ability to remove or buffer the protons associated with lactic acid production accounts, in part, for why some individuals can sustain higher blood lactate levels than others during a steady-state training session. Stroke volume, mitochondria and capillary density, and muscular strength are a few of the variables that affect the clearance of blood lactate. Since an athlete’s improvement will be determined by the performance of

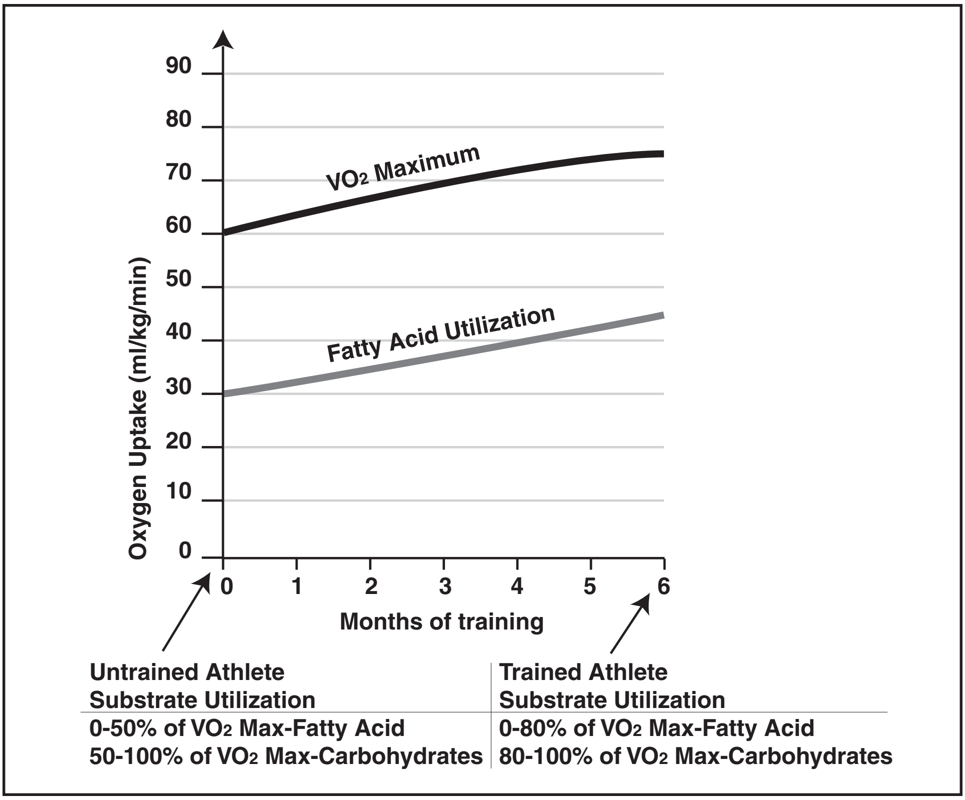

FIGURE 2.7—Adapted from Janssen, 1987

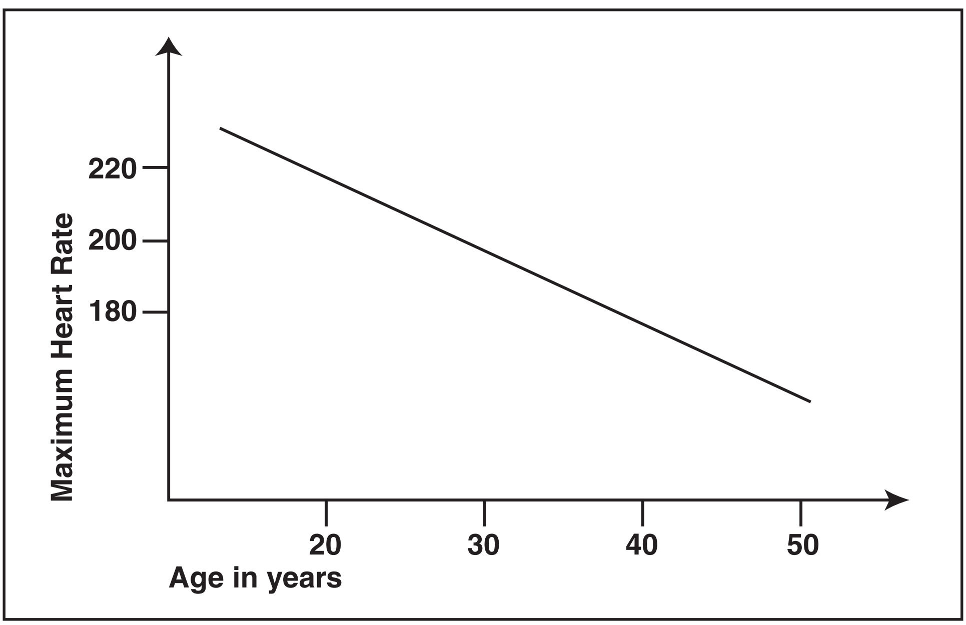

FIGURE 2.8—From Janssen, 1987

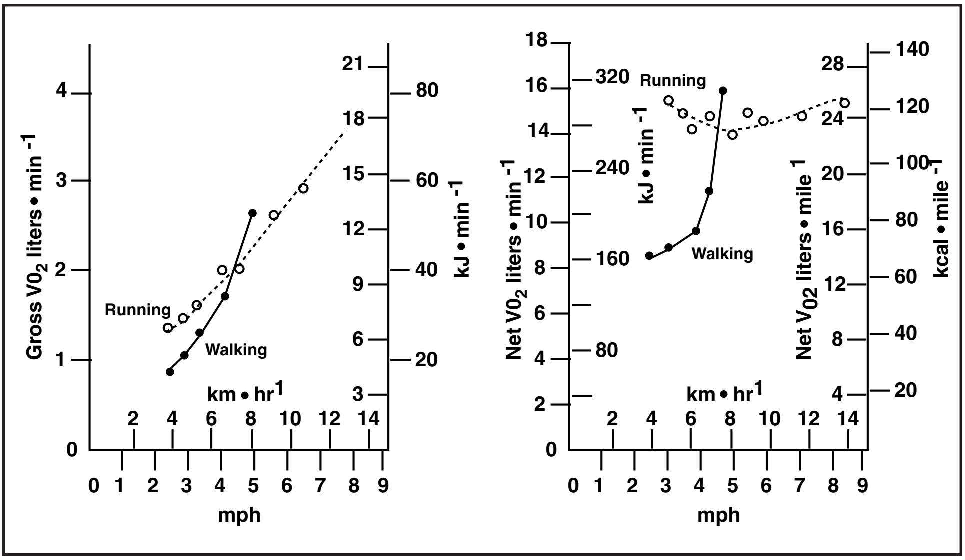

FIGURE 2.9—From Åstrand, 1986

optimal training loads and training frequency, the athlete should run at paces as close to the steady-state as possible, and nearly as often as permitted by adequate recovery. In practice, this translates into two workouts at 3/4-effort, and one at 1/2-effort each week. Given the nature of the anaerobic threshold, the steady-state run can be sustained longer when conducted at a relatively even pace. From the standpoint of available energy reserves, running an even pace at 3/4-effort does not pose a problem, since the slight difference in total energy consumption while functioning aerobically at five, six, or seven minutes/mile pace is not a significant limiting factor. Practically speaking, athletes can run for almost as long at five, as at seven minutes/mile, provided they do so aerobically, as shown in Figure 2.9.

In simple terms, this is the theory behind steady-state training of an athlete's aerobic ability. A steady-state run comprises a relatively long and evenly paced effort: the athlete running near the edge, but not quite crossing the "proton threshold," or then falling rapidly into a state of complete exhaustion. For the exceptionally fit athlete, the 3/4-effort steady-state training session is generally characterized by a heart rate between 165 to 185 beats per minute (bpm), as the athlete functions at roughly 86 to 88% of their VO_2 maximum, and often within 95 to 97% of their maximal heart rate (Janssen, 1987, Coyle, 1995, Daniels, 1998). However, recognize that older, untrained, or relatively unfit individuals perform at much lower physiological values when exercising at 3/4-effort.

To make significant and rapid gains, considerable pressure must be placed on the cardiovascular system. In the late 1970's, Arthur Lydiard shocked many would-be disciples during a visit to Minneapolis by personally demonstrating how the steady-state run should be conducted. Picture a man in his 60's running ten miles at 6:30 minutes/mile pace and lecturing most of the way! The popular

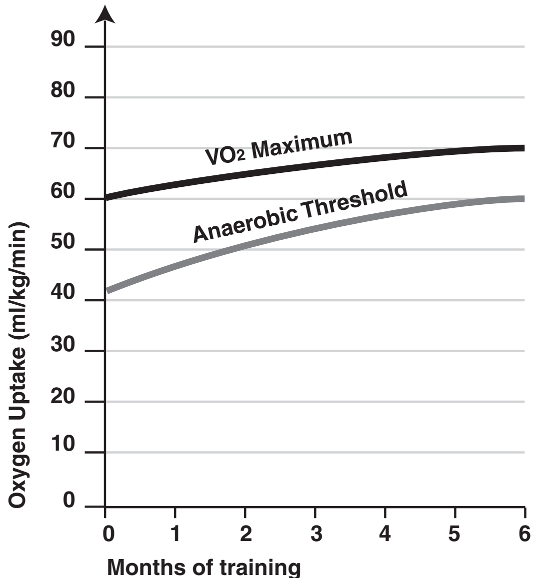

FIGURE 2.10—Adapted from Janssen, 1987

notions of Lydiard as a long slow distance advocate were quickly dispelled. There are different approaches to athletic training. Some are more suited, and some are less suited for a given athlete. But there is no easy way. There was something else about steady-state training that eluded many of Lydiard's listeners. Steady-state training of aerobic ability is necessary, but if used exclusively, it has certain liabilities. It is neither self-sufficient nor the most efficient means of enhancing aerobic ability. What actually happened during those steady-state runs over the testing New Zealand terrain?

Anaerobic Threshold Steady-State

Three variables are highly correlated with running performance: maximum oxygen uptake (or VO_2 maximum), anaerobic threshold (the point below VO_2 maximum associated with the heart-rate deflection point and pronounced blood lactate accumulation), and running economy (how much of an athlete's aerobic ability is actually translated into useful biomechanical work). Evenly paced steady-state runs are actually being conducted near and slightly below the anaerobic threshold, and not an individual's VO_2 maximum. Healthy athletes, who are not yet conditioned, typically encounter the anaerobic threshold at about 70% of their VO_2 maximum. However, given proper training, an evenly paced 3/4-effort steady-state can be run for an hour, covering approximately ten miles, and their anaerobic threshold elevated to approximately 86 to 88% of VO_2 maximum. In practice, athletes will have raised their functional aerobic ability by 16 to 18%. This results in the delayed onset of anaerobic metabolism, and in greatly improved performances, as shown in Figure 2.10.

How can the anaerobic threshold be raised?

> To develop the A.T., the pace must be faster than the highest steady-state pace, but yet not so fast as to push the body into deep anaerobic lactic acid metabolism. In effect, the body carries on a conversation with itself saying "I want to be aerobic and if I can raise my A.T. slightly so as to still metabolize aerobically, I will have made a positive adaptation to stress. So to raise my A.T. all I need to do is raise the triggering mechanism to a higher percentage because I have the maximum VO_2 capacity to handle the workload (John McKenzie, Unpublished Manuscript).

To define an individual's steady-state pace and provide a format for anaerobic threshold training, take the pace that a young athlete can run for ten kilometers (or alternately, ten miles for mature athletes), and use it as a guideline. Relative to the quantity that could be undertaken in an evenly paced effort over that distance, an athlete should subtract 20% for the anaerobic threshold training session. So if an individual can run 10 miles in an evenly paced steady-state, then plan on covering roughly 8 miles in the anaerobic threshold workout. This is an allowance for the inefficiency of the uneven surging efforts undertaken in the anaerobic threshold training session relative to the evenly paced steady-state. Young athletes should then introduce surges 20 to 30 seconds faster than steady-state pace, lasting anywhere between 10 seconds and three minutes, whereas elite athletes can progress to conducting faster segments lasting up to five to 10 minutes. The athletes recover by slowing back down from this faster segment, and then running at their steady-state pace again. However, if one had to pick a single "magic" distance or duration to conduct, it would be 1,000 meters, or approximately between 2:30 to 3:30 minutes duration.

In the abstract, it is not possible to accurately predict or prescribe target heart rate response characteristics for different athletes. For example, an extremely fit elite athlete might run the faster segments with a heart rate over 180 bpm, but the slower segments still above 175 bpm. However, a young untrained athlete or a relatively fit 40-year-old might run the faster segments near 160 bpm and the slower at 150 bpm. Pay close attention to the effort, and if you wish, record the heart rate. But do not prescribe training efforts in terms of heart rate unless it is for an individual athlete whose fitness and characteristic heart rate responses are well known. There is simply too much variability from person to person due to differences in age, sex, athletic level, and training background. Because of this, coaches and athletes should not get too hung up on technology. Technology can be useful, but it is no substitute for judgment and experience. In truth, experienced athletes know what a 3/4-effort is, and also when their pulse rate has recovered to 120 beats per minute. And experienced coaches know a full-effort, 3/4-effort, or 1/2-effort workout when they see it. Moreover, top level coaches and athletes also know what is required in athletic training, and when. Technology such as heart rate monitors and oxygen uptake analyzers can be helpful.

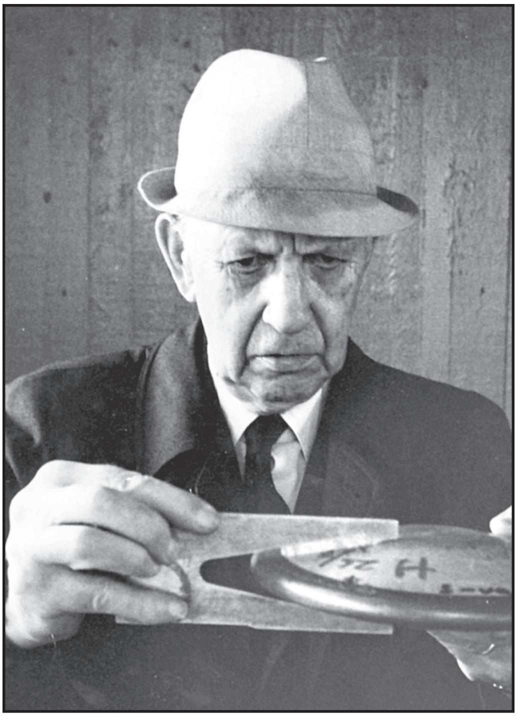

Photo 2.3—Swedish Coach Gosta Holmer, the creator of Fartlek training, who influenced World Record Holders Gunder Haegg and Arne Andersson. Photo courtesy of Emil Siekkinen, Sweden.

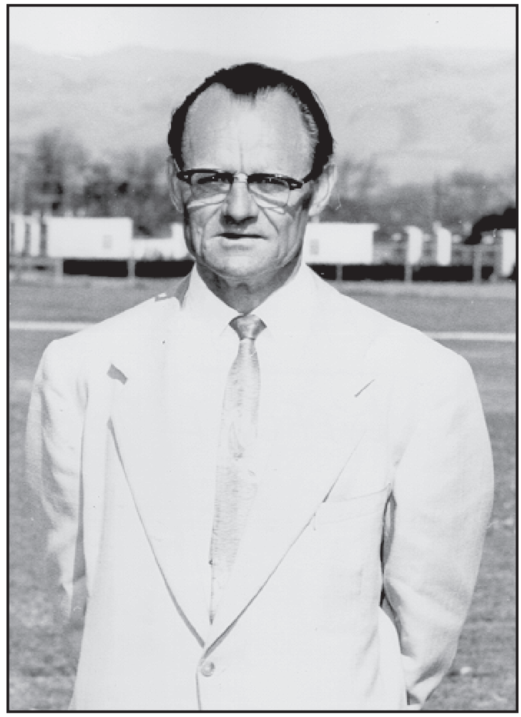

Photo 2.4—Coach Mihaly Igloi, who coached Hungarian World Record holders Istvan Rozsavolgyi and Sandor Iharos during the 1950's. Photo courtesy of Mike Salmon, Amateur Athletic Foundation of Los Angeles.

However, if the fundamental decisions upon which the athletic training is based are faulty, then all runners will have at the end of the athletic season is a lot of fancy data to document their mistakes.

Coaches and distance runners are sometimes overly meticulous when it comes to measurement and recording of detail. Psychologically, this can be a way of exorcising fear, blame, or perhaps bolstering one's confidence. As a result, athletes sometimes become unduly gratified by recording their daily training. Sometimes this comes from the need to prove themselves to themselves, and can be a sign of weakness, rather than strength. For every successful athlete with a detailed diary and various gadgets, at least a dozen other unsuccessful athletes have the same. This doesn't mean you should throw all record keeping and science away, but do not attach too much to it.

> ***No one ever won the olive wreath with an impressive training diary.***
>
> —Marty Liquori

A reporter once questioned Arthur Lydiard while Peter Snell was running a workout in an open field. The reporter asked Lydiard how far Snell was running. His answer: “I don’t know.” Next, the reporter asked how fast Snell was running. Lydiard’s answer: “I don’t know.” The reporter then asked how many repetitions Snell was doing. Again, his answer: “I don’t know.” At that point, Lydiard explained to the reporter that what really mattered was whether Snell was accomplishing the desired training effect with the appropriate effort.

The same principle holds true in the performance of an anaerobic threshold training session. In order to enhance the quality of the training session, runners can vary the length of the faster segments, and alternate shorter and longer surges throughout the session. It is most effective to begin with shorter and slightly faster surges and work into the longer segments, and then return and finish by conducting shorter surges. The anaerobic threshold workout should be tailored to an individual’s main race event, with consideration being given to the distance, number, and intensity of the surges.

This form of training has been around for decades under various names and guises. The practice of fartlek or “speed play” on nature trails, as practiced by Gosta Holmer and the Scandinavians, was a form of anaerobic threshold training. Emil Zatopek ran so-called interval workouts, covering upwards of 10 to 15 miles, stressing various distances while constantly changing the tempo. Some of the so-called intervals were run in the pace of 70 to 80 plus seconds, thus the structure of the interval format as it appeared in the abstract tended to disguise what was actually being accomplished (Kožĺk, 1954). Mihaly Igloi, a trained Hungarian military observer, spent a winter watching Zatopek’s training through binoculars and meticulously recorded the details (Mader, 1979). Igloi then coached the next wave of World Record holders in distance running. Certainly, the training of Percy Cerutty’s athletes in the sand dunes surrounding Portsea, Australia, included considerable training of the anaerobic threshold. Many have also misconceived what Lydiard actually accomplished during steady-state runs. Given the hilly New Zealand terrain, many steady-state efforts were, in reality, anaerobic threshold workouts, as opposed to evenly paced steady-state efforts conducted on the flat.

Accordingly, runners can conduct an unstructured anaerobic threshold workout by simply running a steady-state over a demanding course. Athletes will surge with greater effort on the hills and briefly cross the anaerobic threshold, but then recover on the downhill sections or while running as close to the anaerobic threshold as possible. Mentally, this unstructured approach is less exhausting, and can actually be exhilarating when performed in beautiful natural surroundings. However, merely training the anaerobic threshold is not the most productive way to elevate an individual’s aerobic ability.

Anaerobic threshold and evenly paced steady-state training are both necessary and are actually complimentary. Neither one is fully sufficient as the most efficient means of improving aerobic ability. The most efficient way of doing this

during the base period is to alternate the training efforts. On one hand, the evenly paced steady-state too much resembles simple equilibrium. For the body, equilibrium is bliss, but change and variation results in greater improvement. In the evenly paced steady-state runs, athletes face the constant danger of stagnating by forming neuromuscular stereotypes that will ultimately hinder the acquisition of fitness. They can easily fall into a groove and run at nearly the same pace in the steady-state runs week after week because it has become the dominant habit. Moreover, athletes who only run at an even effort will not be physically or mentally conditioned for executing surges or breakaways in competition. We train to race after all! However, the anaerobic threshold training sessions also have certain liabilities. If athletes only conduct anaerobic threshold work, they might not be physically or mentally conditioned for competitions in which no respite or easing of the pace is provided. Constant change and variation also presents the danger of not adequately stabilizing and consolidating newly gained performance potential. A runner's enhanced aerobic ability would be realized and practically demonstrated by sustaining a faster even pace during a steady-state run. Remember, the pace of the evenly paced steady-state over a given duration is the practical measure of the anaerobic threshold, and indirectly, of the individual's maximum oxygen uptake. The anaerobic threshold training session is like taking a step up on a ladder into empty space: the potential for climbing higher is there, but to fully consolidate that new potential the athlete needs to connect with the next rung on the ladder, in the form of an evenly paced steady-state.

Let's say an individual's steady-state pace over 10 miles is 6:00 minutes/mile, and the athlete conducts an eight mile anaerobic threshold session averaging under 6:20 minutes/mile while alternating surges of 30 seconds and a minute duration at a pace of 5:40 minutes/mile. Suppose that four days later the runner has recovered so that his or her aerobic ability is in a temporary state of enhancement. Now let's suppose the athlete's steady-state pace over 10 miles has potentially improved to 5:55 minutes/mile. If this individual were to conduct another anaerobic threshold session this new potential might not be fully consolidated. The athlete has the potential to run 5:55 minute miles for 10 miles (the concrete and practical measure of the individual's aerobic ability), but the runner's body has never done it! It remains only potential. In a sense, the athlete's performance capability is floating on air. Better to run an evenly paced steady-state at 5:55 minutes/mile so as to assimilate and consolidate this new level of ability. The athlete would then proceed from this building block or rung on the ladder to conduct another anaerobic threshold session, and so repeat the process. Accordingly, the anaerobic threshold and evenly paced steady-state training sessions are complimentary, and both necessary to the most efficient acquisition of aerobic ability. When conducted at 3/4-effort and separated by approximately three to four days, they constitute the two primary quality training efforts undertaken on a weekly basis during the base period.

Many Factors Contribute to an Athlete's Aerobic Ability

The formula for calculating VO_2 maximum is shown below (Fox and Mathews, 1981):

MAX VO_2 = (SV x HR) x (av O_2 difference)

SV = Stroke Volume

HR = Heart Rate

Cardiac Output = (SV x HR)

However, the contributing factors to an athlete's demonstrable aerobic ability are many, and their interrelationships are infinitely more complex than this simple formula would seem to suggest. Edward F. Coyle, Director of the Human Performance Laboratory at the University of Texas at Austin, has attempted to define some of these interrelationships and measure how they correlate with athletic performance. As shown in Figure 2.11, many factors can influence an individual's anaerobic threshold and performance capability.

- Muscle capillary density increases as a result of chronic training loads. The long run on the weekend, and the steady-state and anaerobic threshold running efforts, all stimulate the creation of greater capillary density. Capillary density can enhance performance by providing a greater supply of oxygen, but also by more rapidly clearing and neutralizing the by-products of work associated with lactic acid production.
- If an athlete lacks muscular strength, then running can solicit relatively forceful muscular contractions and result in the occlusion of blood flow in muscle tissue. This would neutralize the practical effects of increased capillarization. Accordingly, Chapter 8 discusses the importance of strength training for middle distance and distance runners.
- Maximal heart rate and stroke volume can also influence aerobic ability. As the heart enlarges, the morning pulse will frequently slow to less than 50 bpm, a condition known as bradycardia. The imposition of a sudden venous preload upon the heart (as when briefly recovering from high-intensity exercises) can enhance stroke volume. For this reason 10 x 100 meters accelerations should be conducted with a short and fast 50 meters jog recovery several times each week during an athlete's warm-up or warm-down. This can be accomplished by running diagonals on the infield of a track and field facility or soccer field.
- Aerobic enzyme activity is largely defined by an individual's genetically determined muscle fiber composition, but can also be influenced by the type of training being conducted and its volume. Proper diet and sound training practices can greatly benefit the central nervous and endocrine systems, and positively influence aerobic enzyme activity.
- Taking naps and getting adequate sleep can have dramatic effects upon athletic development and performance. Like infants or young children,

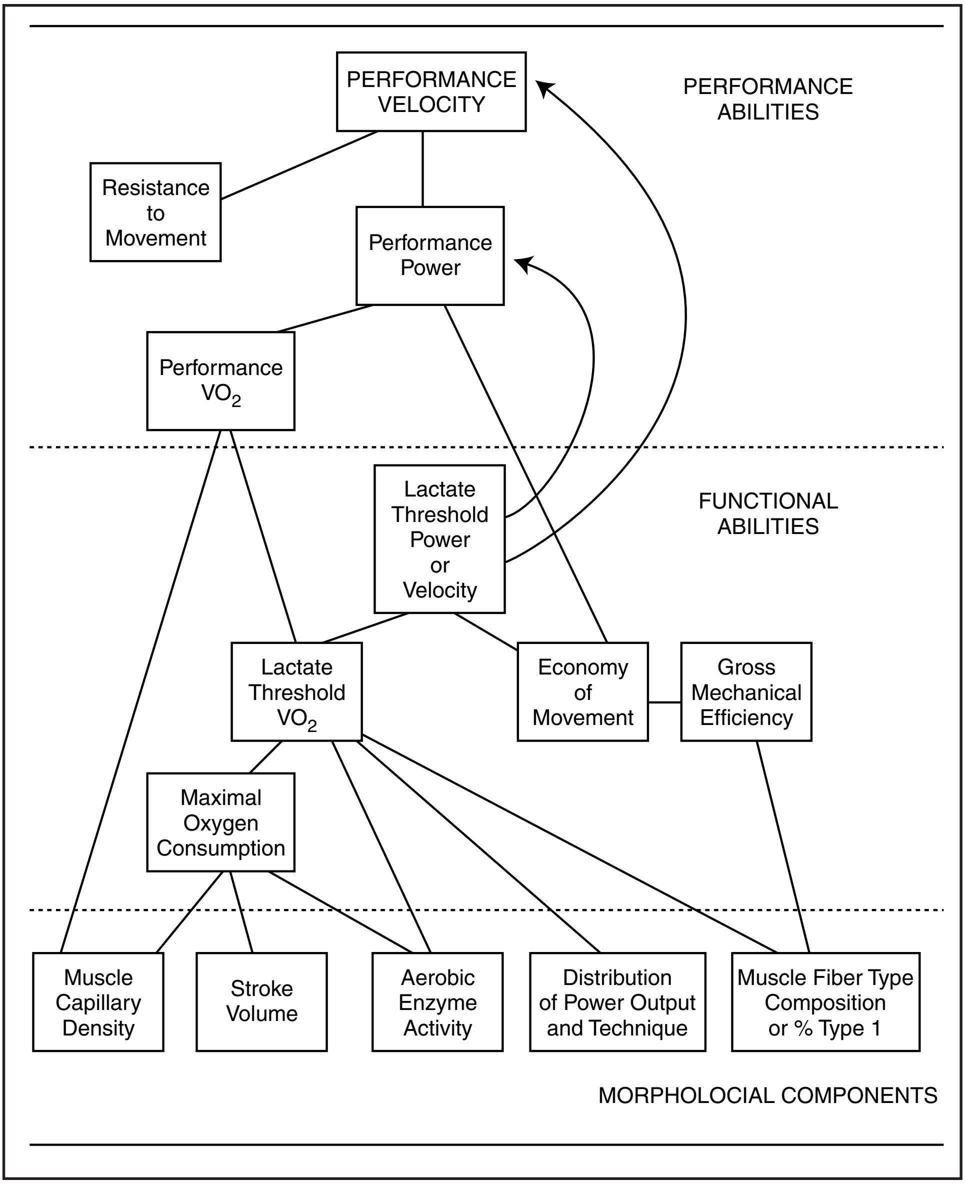

FIGURE 2.11—From Coyle, 1995

developing athletes are also in the mode of acquisition and physical transformation. Young children should take naps in the morning and afternoon, and get to bed at an early hour (Weissbluth, 1987, 1995). Taking even a 20-minute nap several times a day will lower cortisol levels and thereby stimulate anabolic, as opposed to catabolic metabolism. Marc Weissbluth, M.D., Director of the Sleep Disorder Center at Children's Memorial Hospital, Chicago, recalls that Bob Mathias, the 1948 and 1952 Olympic Decathlon Champion, was able to take naps between his events. Herb Elliott, the 1960 Olympic Champion at 1,500 meters, was also able to nap prior to a major contest.

There is a fundamental aspect of athletic training that needs to be understood: The human body is the handiwork of the ages. We are hunter-gatherers, and yes, predators—the twentieth century has certainly proved it (Maile and Selzer, 1975, Goodall, 1990). The human body knows nothing of "athletic training." When we call upon it to exercise at the intensity athletic training demands, it is genetically programmed to presume that the situation is a case of fight or flight, or alternately, a potentially life-threatening quest for sustenance.

When a leopard makes a kill, it will drag the carcass up a tree, then gorge itself and sleep. However, when the leopard misses, it must stay in the hunt until it succeeds, and its metabolism then continues to function in an energy efficient starvation mode, or catabolism. The same thing holds true for athletes out hunting fitness by way of training sessions. If athletes do not drink and eat soon afterwards, and then take a nap or sleep, their metabolisms will remain parsimonious and unduly catabolic. That translates into meager acquisition and transformation of functional ability, thus little or no improvement in athletic performance.

In order to transform its performance potential, the human body needs a few simple cues to tell it that it's an environmentally safe time to spend energy in a relatively uneconomical manner. After all, the process of acquisition and adaptation is something of a luxury, because in nature, a mistake can result in certain death. And the primary cues that the human body pays heed to are exercise, drink, food, and sleep. Athletes do not need to take anabolic steroids or various hormones in order to be successful, rather, they need to train intelligently, and eat and sleep well.

- Running economy is much more significant to performance in the distance events than commonly appreciated. In aerobic exercise, an athlete's running economy directly influences their oxygen demand. All things being equal, as the intensity of aerobic exercise increases, a less economical runner will encounter the anaerobic threshold sooner than another who is more efficient. This is partly why each week, during the base and hill periods, athletes should conduct a 1/2-effort short interval session at date pace that includes reps having a distance between 100 to 400 meters. It is also one reason why athletes should do some barefoot running on grass or a sandy beach whenever possible. The effect of a runner's distribution of power output is discussed in greater detail in Chapter 16. Briefly, athletes who demonstrate a greater range of motion, and more subtle variations and improvisations in their running technique, can effectively distribute the work load over greater muscle mass. Therefore, specific muscle groups and individual muscle fibers do not have to work as hard and will not produce high levels of blood lactate as early during exercise or performance. Many do not recognize and appreciate this aspect of running economy.
- Nutrition can greatly influence a runner's aerobic ability and anaerobic threshold. Athletes and coaches should read and consider Percy

Cerutty's views on diet, and also the similar conclusions of James Autio (Cerutty, 1961 and 1964, Autio, 2000). See also the brief discussion on pre-race diet in Chapter 16.

An entire book could be written on the subject of nutrition, but that lies beyond the scope of this treatment. Accordingly, only a few things will be discussed here. An individual athlete's food intolerances or allergies must be avoided. For example, many are intolerant to lactose (found in milk products), and others to wheat. If you are intolerant and don't know it, then your ability to assimilate nutrition can be compromised, and your immune system may be severely stressed. This will not promote good health or athletic development.

After a demanding workout, athletes should quickly restore their blood pH to a slightly base condition, since this can greatly impact their recovery rate and subsequent performance. A blended citrus fruit juice such as pineapple-grapefruit works well for this purpose. The relatively simple sugars in this juice will also help to restore normal blood sugar levels. Cantaloupe, peaches, watermelon, bananas, mandarin oranges, and almost any form of bread, can also be used. Moreover, taking not only carbohydrates, but also small amounts of protein and fat can enhance recovery. Yogurt can provide about the right amounts, and is easily assimilated. When traveling in foreign countries, a trusted brand of yogurt can also help restore the right bacteria, and provide quick relief from digestive problems that can cause dehydration and severely affect athletic performance. Obviously, an athlete needs adequate stores of carbohydrates for optimal performance. Accordingly, in order to perform at optimal levels, an athlete requires foods with a moderate or high glycemic index in meals preceding a hard workout or competition.

After decades of continual use, the soils in which our food is grown have become nutritionally depleted. For this reason, and because athletes require more than non-athletes, they should take vitamin and mineral supplements.

Obviously, athletes should stay away from all manner of drugs. Alcohol adversely affects performance potential for at least several days thereafter, and is seldom a good idea. Greasy foods or excitotoxins, which create false appetites or tastes similar to MSG, should also be avoided. Note that MSG can be listed as an ingredient under many other names, such as "natural flavors." The caffeine present in coffee is another drug that can impair an athlete when its consumption becomes an addictive habit.

Diet includes what we eat, drink and breathe, but it can also include substances that permeate our skin. In terms of air quality, avoid smog, smoke, paint, new cars and recently laid carpeting. That new car smell is comprised of volatiles, most of which are toxic, and do not enhance performance. Beware of exposure to petroleum products, other harsh chemicals and toxins, and new clothes that have not yet been washed. They can include chemicals that penetrate the skin. Absorption of such chemicals through the skin can sometimes render an athlete anemic. Most people recognize that they can become sick by breathing or eating something harmful, but many are not aware of the skin being